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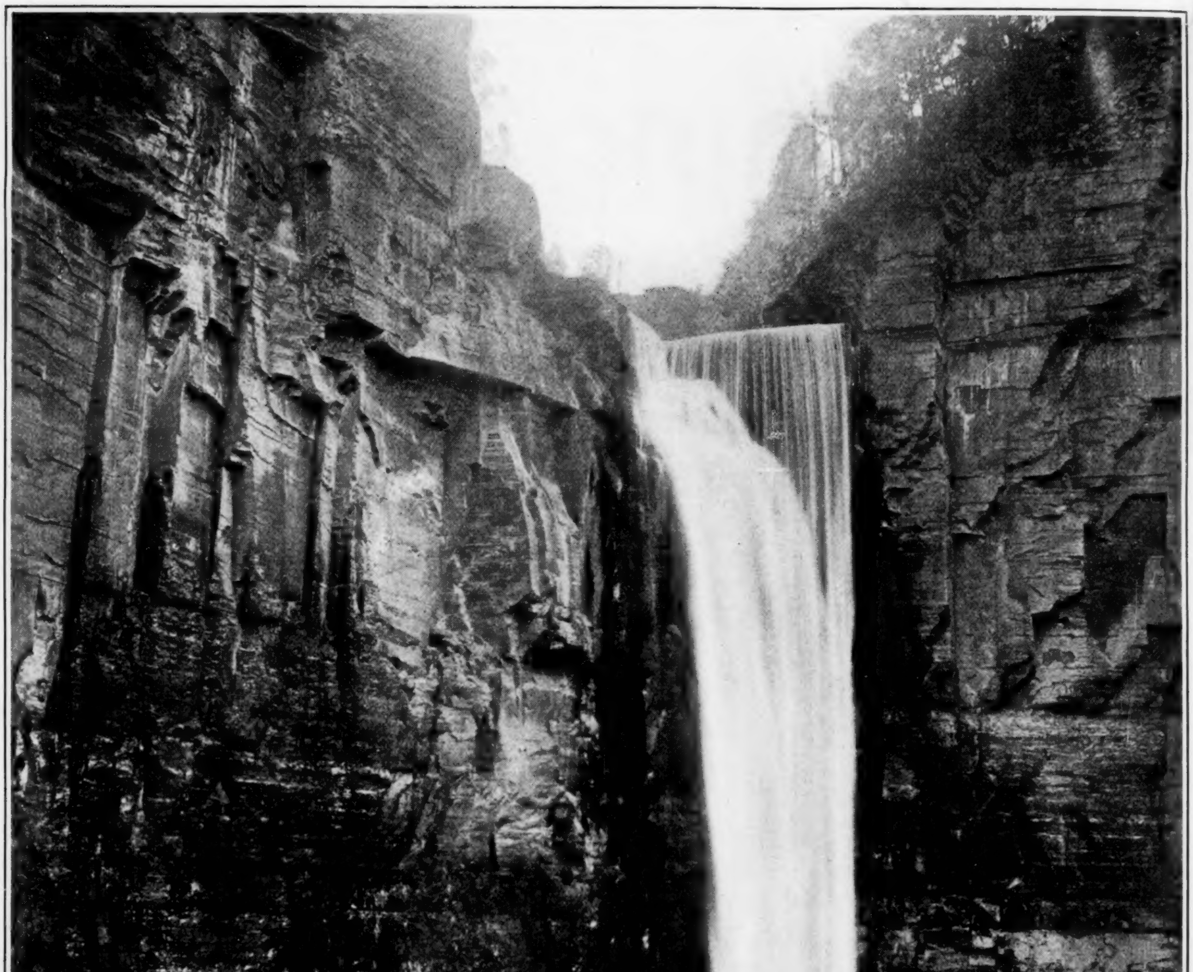

THE FASCINATION OF WATERFALLS AND GORGES—TAUGHANNOCK FALLS, NEW YORK, FIFTY-FIVE FEET HIGHER THAN NIAGARA (SEE PAGE 302)

SCIENTIFIC AMERICAN MONTHLY

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SOAP AND CLEAN HANDS

TIME was when the work of a physician was measured by the vileness of the remedies he prescribed. The more evil the smell, the more disagreeable the taste, the more potent was the medicine supposed to be, and hence the greater the respect commanded by the physician who dealt in such powerful drugs. It must be admitted that there still lurks in many of us a feeling of respect for medical substances which make a decided impression upon our senses of taste and smell. This feeling is especially marked in judging the worth of disinfectants and antiseptics. In dealing with bacteria, it seems reasonable to argue that what is obnoxious to our senses will surely be most disagreeable if not deadly to micro-organisms. For a long time carbolic acid held sway as a popular disinfectant, despite the fact that there were better disinfectants to be had, mainly because of its powerful and penetrating odor. By association, the odor of carbolic acid has come to be regarded as a "clean smell," and phenols have been introduced into soaps for the purpose of appealing to the popular sense of cleanliness which the odor of these chemicals imparts.

Antiseptic soaps have been widely advertised not only as having cleansing properties but being actually of value in cleansing wounds, sores, ulcers, including cancerous infections, and of affording a safeguard in the cases of contagion. There is no doubt that the advertising of these soaps has given the public a sense of security in them which is not warranted.

In order to test the efficacy of so-called antiseptic and germicidal soaps, tests have recently been made in the Department of Hygiene and Bacteriology of the University of Chicago. A report of these tests was published in a recent issue of the *Journal* of the American Medical Association, and it is summarized in the following conclusions:

"Sterile hands are not obtained in the ordinary process of hand washing. More bacteria were found to be removed by the ordinary toilet soaps than by the special soaps. . . .

"The soap solutions obtained in hand washing are of no practical germicidal or antiseptic value.

"The soap left on the hands after washing has no germicidal action.

"In the whole process of hand washing done in the usual manner, the special so-called 'germicidal' or 'antiseptic' soaps exhibit none of these properties. Therefore, these terms are not proper to use in connection with soaps."

"Finally, since the hands may serve as a medium for the conveyance of bacteria in infectious diseases, it is important to remove these bacteria; and this may be done by the ordinary toilet soaps as effectively, if not more so, as by the special brands of so-called "antiseptic" or 'germicidal' soaps."

A JOURNEY ON A RAY OF LIGHT

IT is unfortunately true that the leading American men of science seldom write of their work in a language that the laymen can understand. Of course there are some notable exceptions, but the majority of our scientists have an inborn fear of "popularizing" their work. As a consequence, most of the science that is served to the American public is second-hand material; that is, it does not come directly from the men who know, but from professional writers who attempt to translate and interpret dry and highly technical reports into simple and interesting English. The mistakes of honest translators and the sensational tendencies of unscrupulous writers instead of urging upon scientists the obligation of publishing authentic popular articles, has had the effect of driving these authorities into still deeper seclusion. Such a state of affairs is not only most unfortunate for the general public, but it reacts upon the progress of science which is thereby robbed of popular support; furthermore, because each branch of science has its own technical language workers in one field cannot keep abreast of the progress in other fields.

In Great Britain the most eminent scientists feel no loss of prestige in describing their work in every-day English for the benefit of laymen and of relieving dry statistics with interesting comparisons and occasional flights of fancy, while the French scientists are famous for the literary quality of their popular writings.

On the following page we publish a translation of an article written by Émile Belot, Vice-President of the Astronomical Society of France. In the highly imaginative style so characteristic of the French, he sets his readers astride a ray of light and then sets forth on a journey through the vast sea of space. He tells how, although traveling at the terrific rate of 186,000 miles per second, it takes four hours to reach the outermost planet of our solar system and four hours to reach the nearest brilliant star, Alpha Centauri, but the journey does not stop here. Light years are no longer adequate measures for him and he begins to deal in light centuries. After 600 centuries of travel at this frightful speed, he brings the readers to the globular masses of Delphinus at the edge of the Milky Way. Then leaving our universe and traveling for—between five thousand to six thousand centuries, he arrives at the great spiral nebula of Andromeda. He then proceeds to explain a cosmogonic theory of his own, using simple mechanical experiments to illustrate various phenomena.

We are not going to attempt to criticize Belot's theories, but whether we agree with his views or not, we cannot help but admire the lucidity and the literary quality of his style. We earnestly hope that our own scientists will endeavor to copy the methods of presentation pursued by foreign men of science.

THE GREAT NEBULA IN ORION

THE TRIFID NEBULA OF SAGILTARIUS

Dualistic Theory of Cosmogony*

A New Explanation of the Origin of the Stars and of the Planets

By Émile Belot

Chief Engineer of Government Manufactures and Vice-President of the Astronomical Society of France

When Laplace published, something like a century ago, his celebrated hypothesis with regard to the primal nebulæ he presented it "with that diffidence which is inevitably inspired by all, that which is a result neither of observation nor of calculation." The great astronomer thus manifested with that modesty which always befits science, a penetrating insight into the progress necessary to be made by astronomy when regarded as a science of observation. The solar system at that time was still very imperfectly known—astronomers were still ignorant of the retrograde revolutions and rotations which exist and, therefore, supposed that the revolution of all the stars in our system was direct like that of the earth. Of a thousand small planets today carefully catalogued only four were known. The telescope had not yet revealed the strange forms of the spiral nebulæ, of which as we now know there are probably a million in existence. The camera, that incomparable eye, which accumulates for a hundred hours luminous impressions upon a single plate, while the human eye can take them in only during a tenth of a second, was not yet invented. Finally, the spectroscope had not yet revealed the unity of the chemical composition of the stellar universe and the radial velocity of those stars whose very distance is immeasurable.

But how would it be possible for astronomers to fail to make use of all these new discoveries, of which Laplace was ignorant, to construct a new cosmic synthesis to explain the origin of worlds? Let us begin by trying to learn a little bit about these worlds of which scarcely one inhabitant of our planet has any idea, thanks to the injustice—so much deplored by the master, Camille Flammarion—with which astronomy, the noblest and the most instructive of all sciences, is ostracized in the schedules of the schools.

*Translated for the *Scientific American Monthly* from *La Science et La Vie* (Paris), August-September, 1920.

THE IMMENSITY OF THE UNIVERSE AND THE VARIETY OF SIDEREAL SYSTEMS

Let us quit the earth leaping astride a ray of light, which, traveling at a velocity of 186,000 miles per second has taken 8 min. 18 sec. to come from the sun, passing on its way the planets of Mercury and Venus. In a trifle more than another second we shall reach the moon (221,500 miles distant); in 4 min. 20 sec. more we shall come to Mars, but it will take us a quarter of an hour longer to cross the zone of a thousand little planets before reaching Jupiter in the course of 35 min., Saturn in 70 min., Uranus in 2 hr. 30 min., and Neptune in 4 hr. (Fig. 1). Along our path we shall meet many comets, which, remote from the sun, possess no tails, and indeed are scarcely visible, being merely small spherical nebulæ.

The sun now looks to us merely like some great star, but we shall not leave its sphere of attraction until our journey has continued for two years; for we shall not reach the nearest brilliant star, α, Centauri, until after four years of travel, during which we shall have covered a distance of twenty-four thousand billion miles. Here our first surprise awaits us: the star α Centauri is a double star composed of two suns gravitating about each other. Our own single sun, situated at the center of our system, is an exception, as we shall find, for in our ultra-rapid journey we shall encounter not only many double suns but many that are triple, quadruple, etc.

But now we must begin to count by centuries in the record of our voyage. In an extent of space measured by from one to three centuries we shall encounter the great amorphous nebulæ, Orion, Cygnus, etc., faintly glowing gaseous masses

which doubtless form part of the original raw materials employed in the formation of worlds and which contain above all hydrogen and helium. At the end of sixty centuries of this journey of fantasy we shall have had the opportunity to count a billion or two of stars; we shall have had a fleeting glance at millions of planets revolving around fixed stars and bearing billions of human beings, whom we shall never have the pleasure of knowing! And yet we shall have arrived only at the edge of the central nucleus of the Milky Way, and not even at those star-clouds which resemble in photographs a

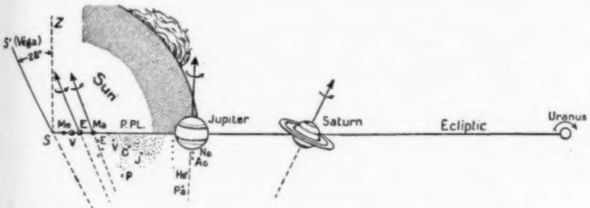

FIG. 1. RELATIVE PROPORTIONS OF THE PLANETS IN THE SOLAR SYSTEM (EXCEPT NEPTUNE)

The scale of distances is of course much smaller than the scale of sizes. The relative size of the sun is indicated by the partial section.

golden dust cast into the infinite shadow of space. Here, perhaps, we shall see the birth of a world, of a planetary system like our own, from the shock of a gaseous star coming into collision with a nebula in one of those sudden conflagrations, which reveals itself to us as a "Nova."

Having now had the patience to admire this majestic spectacle during a journey of six hundred centuries, traveling at a velocity of 186,000 miles per second, the celestial horizon will at last appear free from all stellar dust. What awaits us beyond? In the direction of Sagittarius we shall perceive masses of stars which have been called the Island Universes; these open or globular masses are gigantic agglomerations, each one of which may contain from 30,000 to 100,000 suns, a sphere of fire turning round an axis like a lighthouse illuminating the infinite ocean of ether. Let us stride across one of these masses (that of the Delphinus) with our seven-leagued boots, which would necessitate a journey of 2,000 centuries and which appears to be at the extreme confines of one of the spirals of the wonderful Milky Way.

Let us dive now into sidereal depths; we shall now perceive only spiral nebulæ, i.e., the other milky ways—the universes external to our own, which are numbered by millions. The nearest one is the spiral nebula of Andromeda, which rushes toward us at a velocity of 180 miles per second, and wherein the telescope has already beheld the birth of no less than fifteen new stars. And how far is Andromeda from us? Possibly at a distance, which measured in years of light, amounts to from 5,000 to 6,000 centuries.

Thus we measure velocities, thus we observe cosmic shocks and record phenomena which took place at least 200,000 years ago and probably more than 500,000 years ago! We are photographing today stars which must have ceased to exist before man made his appearance upon earth. Behold the grandiose and impressive tableau of the Cosmos revealed by modern astronomy. How different this is as regards space and time from the infinitesimal sidereal horizon known to the astronomers scarcely a century ago.

COSMOGONIC PROBLEM FROM THE VIEWPOINT OF EVOLUTION

It is thus that the cosmogonic problem confronts us with all its frightful complexity of which Laplace could have had no suspicion. It is no longer a question of explaining the origin of our own little solar system alone. Such is the unity of the cosmic plan that we must at the same time take into account the strange forms and movements of the spiral nebulæ of the Milky Way, of the formation of the masses of stars, and of that of the Novæ. Spectrum analysis has shown us the unity of the chemical composition of the worlds; all known physical forces are as universal as gravitation. Geometry is almost plane in all the systems: the satellites gravitate in the plane of the equator of their own planet as do the planets around the sun in the plane of the ecliptic. The Milky Way is almost plane as are also the spiral nebulæ; the proof of this is given by such of these nebulæ as are seen edgewise. All these facts converge toward the idea that the evolution of all cosmic systems has been the same at all times.

But what do we learn from the evolution of all living organ-

THE GREAT SPIRAL NEBULA OF ANDROMEDA

NETWORK NEBULA IN CYGNUS

isms? This evolution is very rapid at the beginning, when each one fixes in a few days or months, at most, the distinctive characters and the geometric structure of its species. If the force of *attraction* had presided at the evolution of the cosmic organism, this evolution would have been, on the contrary, very slow at the beginning.[1] Moreover, the operation of the force of attraction would inevitably have produced a *concentration* of all the matter of a system into a single mass; but as an actual fact there is, on the contrary, a *dispersion* of masses of matter around a center, satellites around a planet, planets around the sun, of divergent spirals in the spiral nebulæ.

The Force of Attraction Insufficient to Explain the Structure of Worlds.—Following this train of reasoning a primary conclusion is forced upon us: *The force of attraction is incapable of explaining the structure of worlds.* We must seek their origin in the *dispersive forces of great velocity* found in the *stars having a brief evolution*, which are, so to say, *the embryos of suns;* but it is a fact that such stars exist—they are the new stars, the so-called "Novæ."

But the idea of evolution evokes also the idea of the variety of species. Our present knowledge of the hereditary characters discovered by Mendel enables us to possess a precise knowledge of this variety, by means of the multiple combinations of the dominant characters in the two parents. In a word, the variety of species proceeds from the *dualism* which presides at the birth of new organisms. May we not say that the unity of the cosmic plan, the well-proved variety of the sidereal species, is due to their *dualist origin*, and is not the coming together of two already differentiated cosmic types required to engender each star in the universe? As a matter of fact we are familiar with such unions in the heavens—it is these which result in the Novæ, those strange stars marked by an extremely rapid evolution. And these encounters, which are naturally produced frequently in the Milky Way, where the cosmic matter is particularly abundant, have the character of actual shocks, since in the course of a few hours Novæ like that of Perseus (1901) .and that of Aquila (1918) pass from the 11th magnitude to a brillance much superior to that of Sirius, i.e., they are 150,000 times as bright in the morning after their discovery as they were upon the evening before.

THE STAR CLUSTER IN CANES VENATICI

In our laboratory, as in our atmosphere, a shock produces light, and vibration, a dispersion of the matter surrounding the point of shock; behold the origin of those dispersive forces which dominate the force of attraction—those forces whose action is enormously rapid and which the idea of evolution has led us to seek in the cosmic realm. Thus, in the initial shock of the revolving stars which gave them birth the satellites would be merely spattered fragments of the planetary nucleus; the planets spattered fragments of the solar nucleus; and the spirals of the spiral nebulæ centrifugal jets of their nucleus.

Our theory of a dualist cosmogony which, starting with the Novæ, studies the cosmic shocks and the translation in space of the nebular stars producing their encounters, is thus in complete opposition to other cosmogonic theories, whether these be monist like that of the school of Laplace, wherein translations in space do not occur, or even dualist like that of Chamberlin-Moulton (planetesimal hypothesis) in which there intervene only *semi-shocks at a distance* or cosmic tides in which only gravitation enters into the calculation of savants.

The History of a Nova.—What then is the modern view of the history of a Nova? A small gaseous star or planetary nebula, so small (the 11th magnitude) as to be barely perceptible upon the photographic plate, attains in the course of a few hours, by means of a violent encounter (impact) with a cosmic cloud, a brilliance equal to that of a star of the first magnitude. Is the Nova a dark sun whose inner flames have suddenly broken through its crust? No! For the continuous spectrum, which is always feeble, rapidly disappears, giving place to the spectrum which characterizes nebulæ, which is that of the cosmic clouds. The hydrogen, which is very abundant, is revealed by its brilliant lines which are often displaced toward the red, and by its dark lines which are greatly split and displaced toward the violet; and the sheets of the stellar nucleus thus detached approach the earth at fantastic velocities, sometimes attaining, as in the Nova of Aquila (1918), a velocity of 1,400 miles per second.

Afterward the brilliance of the Nova diminishes, often by periodic oscillations; we behold it surrounded by concentric nebular sheets of constantly expanding diameter. Do not photographs in this case exhibit the planetary rings of a system in process of formation? And note that in the course of two years the evolution comes to an end by the return of the Nova to its original degree of brilliance, but with the characteristic lines of the Wolf-Rayet stars, i.e., the helium lines which are both the yellowest and the hottest.

Must we regard this prodigious and rapid evolution as being a cataclysm like the end of a world, volatilized by fire? *Solvet saeclum in favilla.* Not so! Our optimistic cosmogonist sees herein, on the contrary, the origin of a solar system, whose period of gestation is short like that of any other embryo; he interprets the luminous shock of a Nova as the "let there be light" preceding by many days the light of a condensed sun, and announcing to the universe by its shining message the birth of a new planetary family.

THE NEW DUALIST AND VORTICAL COSMOGONY—ITS PROOFS

It is by this method that I have succeeded in solving the problem of the origin of worlds. Modern science is well accustomed to wiping off the slate former ideas which had appeared to be absolutely fundamental; e.g., the constancy of the mass, which is now known to vary with the velocity; the permanence of atoms, which are in fact disintegrated by radioactivity; the impeccability of Newton's law, which Einstein now declares requires a correction which depends upon the velocity of light.

Modern astronomy must in its turn learn to accept the paradoxical idea that the architecture of worlds does not depend upon the *force of gravitation.* We must, first of all, furnish an explanation of this paradox: Gravitation may be in the beginning *inoperative* or *latent;* when two greatly extended nebulous stars encounter each other in space their centers of gravity are very remote from the surfaces of shock: hence their mutual attraction is able to impart to them merely a

[1]The velocity of condensation of a gaseous sphere is in inverse ratio to the square root of the radius.

very small velocity, a few miles per second, whereas the comparative velocity of the impact may attain to more than 1,000 miles; in such a case the force of gravitation is *inoperative*—it is merely a feeble disturbing force among the dispersive forces due to the cosmic shock.

It may also happen, as I demonstrated quite recently, in a note read before the Academy of Sciences, that the attraction may be constantly in a state of equilibrium with the centrifu-

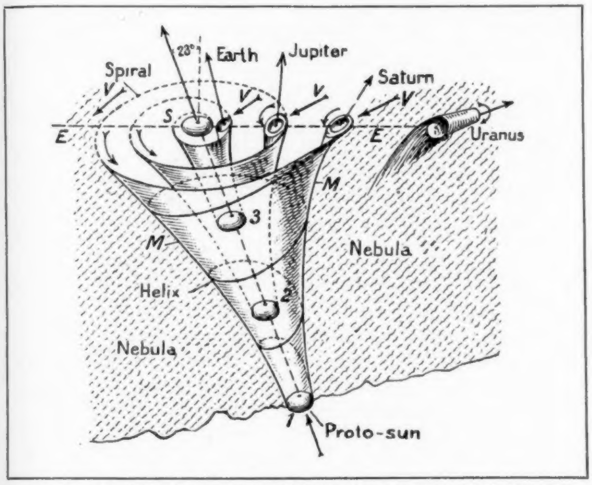

FIG. 2. DIAGRAM OF THE FORMATION OF THE PLANETARY SYSTEM BY THE IMPACT OF THE PROTO-SUN UPON THE PRIMAL NEBULA

The shock, through the vibration of the solar nucleus which it occasions, causes the vertical planetary sheet to be detached at 1, 2, and 3; the velocity V of the nebula pushes back and agglomerates each sheet into a planet whose axis diverges from the direction of the apex in a degree which is directly proportionate to its distance from the center S of the sun.

gal force operative along certain cosmic trajectories; in this case the attraction is *latent* and calculations include only the dispersive forces due to the impact.

This idea liberates us from an exclusive dependence upon the law of Newton;[2] emancipated from a slavish dependence on this law, we at once perceive that the celestial mechanics concerned in the origin of worlds is identical with the ordinary physics and mechanics whose laws govern fluid masses such as those with which we are able to experiment in our laboratories, and the perception of this fact simplifies remarkably the riddle of the origin of worlds. In order to solve this problem let us simply apply the method so successfully employed by the founders of modern astronomy, Kepler and Newton, those men of genius who unconsciously applied in their researches the inductive method of the physical sciences, Kepler discovering empirically his three laws applicable to planets[3] and Newton seeking the theory capable of explaining their mathematical forms.

Following their example I have sought to find by empirical methods new laws operative in the solar system. I have succeeded in finding two such laws: *the law of the distances of planets and satellites from their central star* and *the law of the rotations of planets about their axes.* Each of these laws comprises in its formula two terms: Hence the concept of a dualist cosmogony. In a word, it was in seeking the mathematical explanation of these two laws that I discovered a new cosmogony: according to this, two bodies were concerned in the origin of each star in our system; these bodies upon their encounter in a nebular state engender according to the well-known hypothesis of the great physicist, Descartes; the whole theory of the new cosmogony is implied in the law stated below.

VORTICAL COSMOGONY: A DUALIST HYPOTHESIS

All stars and all sidereal systems result from the encounter of a gaseous spheroid S (Fig 2) in a state of rotation and an amorphous nebula in a state of translation into which the nucleus S penetrates.

Instead of stating in this place the complicated mathematical proofs which can readily be found elsewhere I shall merely set forth certain physical facts revealed by these calculations and explain how analogous phenomena can be obtained in the laboratory.

1. *The Phenomenon of the Vibration of Pulsation of a Gaseous Sphere.*—Let us begin by producing a large soap bubble made from Plateau's liquid which is composed of water, soap, and glycerine; this bubble S_1 (Fig. 3) is then blown upward and we shall observe that the soap bubble becomes flattened alternately at the equator (E_1 E_2), and at the poles (P_1 P_2). If one were able to blow upon the bubble with sufficient strength yet without causing it to burst, the equatorial matter would be projected at E_1 E_2 in the form of a sheet (N_1 N_2)

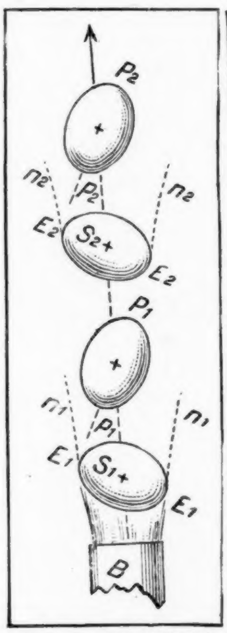

FIG. 3. VIBRATORY PHENOMENON OF PULSATION OF A GASEOUS SPHERE

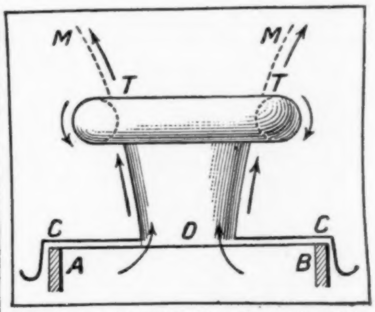

FIG. 4. TRANSLATION OF A GASEOUS SURFACE IN A RESISTANT MEDIUM ILLUSTRATED BY SMOKE RINGS

M M trajectory of smoke ring T issuing through hole in box *A B*.

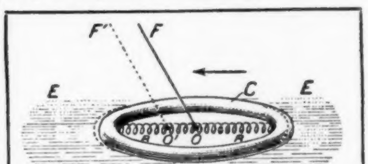

FIG. 5. ECCENTRICITIES OF ORBITS EXPLAINED THE EXPERIMENT OF THE FLOATING RING

having a circular section and this ring-shaped sheet of matter would separate from the bubble. Moreover, since the pulsation of the bubble is, like all vibrations, periodical in character, the positions S_1 S_2 of the equatorial expansion are equidistant in the direction S_1 S_2 of the arrow.

Let us now compare this experiment with Fig. 2, which presents a diagram of the formation of the primal solar system. The gaseous sphere of *proto-sun* having a radius 62

[2] Newton's law is beautifully simple: Every particle of matter in the universe attracts every other particle in direct proportion to their combined mass and in inverse proportion to the square of their distances.

[3] The first law of Keppler established the *equal description of areas* in the following terms: Imagine a line drawn between the sun and a planet: so long as the planet continues to move upon its ellipse this line, which is called in astronomy the *vector radius*, will *describe* or *pass over* portions of the area or of the surface of the ellipse, and the movement will be such that the *vector radius will describe equal areas in equal times* upon whatever point of the ellipse the planet may be. The second law, in virtue of which the planets describe ellipses having the sun as their focus, determines the law of solar gravitation for each planet independently of the other.

According to the third law the squares of the periodic times of the planet (i.e., the time required by them to travel over their orbit about the sun bear the same ratio to each other as the cube of their average distances from the sun.

times as great as that of our present sun rushes against the nebula, the point of shock being situated at 28° from the pole in the direction of the apex[4] toward the star Vega.

The proto-sun thereupon begins to pulsate, expanding at the equator in the position 1, 2, 3, etc. If the pulsation be sufficiently intense *planetary sheets* will detach themselves from the equator forming in the nebula, progressively expanding "tulips" moving toward the primal ecliptic E E. Each of these planetary sheets will inevitably present a *vortical surface* since each molecule therein describes a spiral by reason of its rotation around S and its movement of translation.

2. *The Phenomenon of the Movement of Translation of a Gaseous Surface in a Resistant Medium.*—In this case also a simple experiment will assist us to comprehend the matter. Let us produce some tobacco smoke in the box A B; then let the lid C C which is pierced with a round hole O (Fig. 4) 10 cm. in diameter, be suddenly lowered. By this means we shall succeed in projecting into the air large smoke rings which will expand progressively as they travel from O to M. It can be demonstrated that the curve MM is a logarithmic curve The curves defining the apparent contours of the planetary sheets (Fig. 2) thrown off at 1, 2, 3, will also be logarithmic in nature, since it is readily understood that these sheets are essentially gaseous projectiles like our rings of smoke traveling through the resistant medium of the nebula.

Consequently it is possible to calculate the distances from the sun at which the planetary sheets (and the planets themselves) were situated when they reached the primal ecliptic EE, but the theoretical law thus discovered is verified with great precision by the actual distances of the planets and also by the distances of the satellites from their respective planets.

THE LAWS GOVERNING THE DISTANCES AND THE INCLINATIONS OF THE PLANETARY AXES

The Ratio of the Distances of Two Consecutive Planets (or Satellites) from the Proto-sun (or Planetary Nucleus) Is Constant.—Thus we see that the law of distance which the Newtonian mechanics had never been able to demonstrate is the first new conclusion obtained from our theory of vortical cosmogony, but there is also a second new conclusion which has hitherto remained entirely unsuspected by astronomers:

We see in Fig. 2 that the curves MM cut the ecliptic EE at various angles which deviate more and more from the direction of the apex. But these angles are precisely those which are formed by the axes of our planets with the axis of the ecliptic; consequently there exists a law governing the inclination of the planetary axes which may be stated as follows:

In the beginning all the planetary axes are in the same plane, which is perpendicular to the ecliptic, and they comprise the direction of the apex where they converge to a single point (see Fig. 1). If the earth has its axis inclined to that of the ecliptic at 23° 27′ it is because it is near the sun, whose direction of translation forms an angle of 28° with the same axis. Jupiter being farther from the sun has its axis almost perpendicular to the ecliptic. Saturn (28°) has its axis even more inclined than that of the earth. But Uranus is twice as far as Saturn from the sun; what then must have occurred in the case of this planet? Its planetary sheet must have been rolled back by its passage through the nebula to such a degree as to form an actual ring (like the smoke rings of our experiment) and hence its molecules must revolve about an axis lying upon the ecliptic. Thus we see that this supposed anomaly, which is entirely incompatible with the cosmogony of Laplace, finds an immediate explanation in our own theory.

PLANETARY ROTATIONS, ECCENTRICITIES OF ORBITS, ETC.

Our theory indeed explains with a like facility various phenomena which have proved stumbling blocks to other cosmogonists.

Direct Rotation.—The complicated explanations of direct rotation proposed by Faye and H. Poincaré have never convinced anyone else. In the cosmogony proposed by me the cause of the direct rotation of the planets in the vicinity of the sun is a matter of intuitive reason. At the same time we can readily understand why there is in general only one large planet or ring per planetary sheet. The amorphous nebula has a component of translation V from the rear to the front (Fig. 2), i.e., in the direction opposite to the velocity of the planetary sheets at the moment when they cross the line SE. Their velocity is diminished by this retardation; they, therefore, have a tendency to fall toward the sun, but being drawn backward in their movement by the attraction of the remainder of the planetary sheet, they roll up with a movement which is direct and not retrograde; this motion is that of the planetary sheets because of the fact that it is also the direction of the rotation of the proto-sun.

Eccentricities of Orbits.—But what is the reason that the planets in the beginning (as well as at the present time) did not revolve around the sun in a circular path but, on the contrary, in slightly eccentric orbits or ellipses? Let us answer this question by means of another experiment. Let us represent the circular planetary sheet by a circle C floating upon water (Fig. 5) which like the nebula is a resistant medium; let us represent the attraction of the sun O by springs connecting the points of the circle with the center. Then let us subject this material ensemble to an oblique traction OF by means of the cord attached at the point O. We shall then observe OF displaced to the position O′F′ indicated by the dotted line, because of the resistance of the circle C to movement in the resistant medium—hence O′ is no longer at the center of the circle. In the same way the movement of translation of S is oblique to the plane of the top of the planetary sheets (Fig. 2), it is evident, therefore, that they must be eccentric. Their center in the beginning being to the right of the solar center S which carries them along in space.

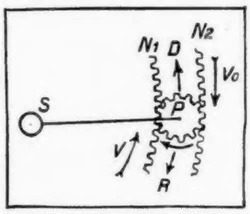

FIG. 6. DIFFERENTIAL MECHANISM ILLUSTRATING RETROGRADE RELATIONS

Comets and Movement of Retrograde Revolution.—It might seem to the uninitiated that our cosmogony would find it as difficult as does that of Laplace to explain movements of retrograde revolution and of those comets whose greatly flattened orbits are almost parabolic in nature—but this is not the case. Let us consider for a moment the piece of mechanical apparatus known as a *differential* which consists essentially of a pinon P revolving around the center S and meshing with two toothed sectors N_1 N_2 (Fig. 6). In the cosmic reality S represents the sun, N_1 a planetary sheet, with the velocity V having a direct movement N_2 the amorphous nebula with the velocity V_0 moving in the retrograde direction with respect to S. It is the conflict between V_0 and V which creates the local planetary vortex P, thus insuring that the future planet shall rotate upon its axis. Let us now examine what will take place in the retrograde region of the solar system, i.e., beyond Uranus. To begin with, we have the following data: V is greater than V_0; the planet P working in mesh with V and V_0 *will have a retrograde rotation* and will be carried along in the direction of the arrow D (*direct revolution*)—we find this to be true of Uranus and of Neptune. But let us travel farther away from the sun: the velocity of the orbit V diminishes in accord with the third law of Keppler, V_0 remaining constant. At any given moment, therefore, V is smaller than V_0. *Hence the planet P will continue to have a retrograde rotation*, but will be carried along in the direction R (*retrograde revolution*). No planet having a retrograde revolution is known to us, but certain satellites—IX of Saturn, VIII and IX of Jupiter—possess a retrograde revolution, and I may mention with regard to the last two that before their discovery I myself had predicted that their revolution would be retrograde as will

[4]The apex is that point of the heavens toward which the solar system is directed in its translation through space.

be that of all the external satellites and of the planets which may be discovered in the future *at a greater distance than 100 astronomical units.*[5]

But what will happen when V equals V_0, which occurs at about this distance? In this case there is probably a collision between the masses V and V_0, but no tendency to the rotation of P, i.e., no vortical agglomeration. As soon as a mass V

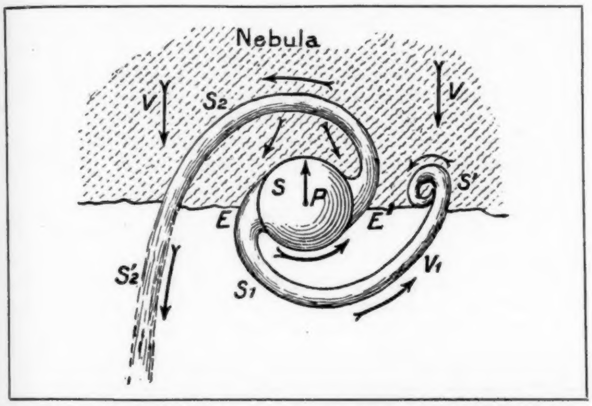

FIG. 7. FORMATION OF A SPIRAL NEBULA BY IMPACT OF ROTATING NUCLEUS S AND AMORPHOUS NEBULA

The shock forms two swellings EE which extend radially and which, animated by a movement of rotation, produce the spirals S_1, S', S_2.

encounters as mass V_0 their orbital velocity is annulled, but since the sun continues to attract them and since this attraction is not balanced by centrifugal force, they will be precipitated in a straight line toward the sun; *these are the comets,* nebular masses without agglomerations and having highly eccentric orbits, which may, furthermore, have the said eccentricity greatly reduced when passing near Jupiter and Saturn by a so-called "*capture.*" There may also be comets produced by the extreme portion of the streamers into which the solar mass stretches out to a greater or less degree the original nebula, according to the beautiful theory of Schiaparelli.

THE SPIRAL NEBULAE AND THE STRUCTURE OF OUR UNIVERSE

The hypothesis of the dualist synthesis of the solar system, indeed, satisfies the intellect by the multiple numerical or qualitative verifications, whose principles we have set forth. But it remains to explain the structure of our universe (the Milky Way) and that of the other universes (the Spiral Nebulæ)—and the fertility of the dualist hypothesis enables us to do this.

The planetary sheets detach themselves from the equatorial region of a rotating gaseous nucleus because of a shock upon the *polar region;* these planetary sheets are projected from the nucleus along radial lines. It is the shock upon the *equatorial* region of a rotating gaseous nucleus, on the other hand, which will reveal to us the secret of the spiral nebulæ—thus the problem of cosmic shocks may be analyzed into two entirely distinct cases, which give rise respectively to systems whose geometric forms are entirely different.

Let us imagine (Fig. 7) a nucleus S whose poles are at PP', whose equator is at EE' in the plane of the figure and which has the relative velocity V when it encounters the nebula N. The shock will produce two diametrically opposite swellings EE' which will tend, after their radial projection to revolve around the axis P, since they participate in the rotation of the nucleus. In reality the periodical pulsation of the latter will give rise to periodical projections which will gradually produce the two spirals S_1 and S_2 which will very soon become merged in the nebula N. The velocity V will have a very different effect upon these two spirals: it will tend to roll up the spiral S_1 to the point at which its velocity V_1 will be opposite to V, which will create a secondary nucleus S', revolving in the same direction as the nucleus S; the spiral S_2, on the contrary, drawn out by the same velocity V, will be finally expanded in space into S'_2.

But as a matter of fact these very simple consequences of the theory are actually realized in the nebula of Canes Venatici, which like many other similar nebulæ presents a secondary nucleus with a re-entering orbit; we even observe upon the other spiral a rolled back nucleus which would be represented also upon our diagram if the spiral S'_2 had been prolonged sufficiently to make another half turn around the nucleus.

Let us remark next that these secondary nuclei are the result of the phenomenon of *unilateral formation* with rotation, exactly like that of the planets shown upon the right side of Fig. 2; furthermore, the theory made known by me in 1909 shows that the spirals revolve in the same direction as the nucleus, though it was not until 1916 that the measurements made by Van Maanen confirmed my predictions, whereas until that time all astronomers were convinced either that the rotation of the spirals was in the inverse direction or else did not exist at all. Today this error has been banished.

The Milky Way.—Let us now consider the Milky Way, the spiral nebula of our stellar universe: I conceived the idea quite recently that our Milky Way might be identified in plane with the nebula of the Canes Venatici. We may see how far this induction is verified by examining Fig. 8 where there are reproduced together with the diagram of this nebula the constellations of the Milky Way upon a circle having the sun as its center. Charlier has taught us that the center of the nucleus of the Milky Way is in the vicinity of Argo Navis; we know, of course, that the most brilliant portion of the Galaxy (i.e., the part nearest us) is in the vicinity of Cygnus.

THE SPIRAL NEBULA IN CANES VENATICI

Allow the eye to travel around the Galactic circle in the retrograde direction; we shall see successively one branch, then two branches, and even three, superposed (or nearly so, if they are not actually in the same plane), and this is precisely what has been proved to be true.

Globular Masses, etc.—Hitherto no one has found it possible to explain why the globular masses have a unilateral concentration upon the side of Sagittarius: we now know that it is because the velocity V of the nebula N of our universe has

[5]The astronomical unit is the distance from the earth to the sun.

acted precisely as was predicted in our theory to crowd back or roll up the external spiral, and this as has also been proved, in the same direction, thus producing the condensation of a secondary nucleus of the spiral nebula of Canes Venatici.

Yet more: we see upon the figure that the mass of Centaurus should be the nearest, the others (Sagittarius, Hercules, Delphinus, etc.) being more and more remote upon the external

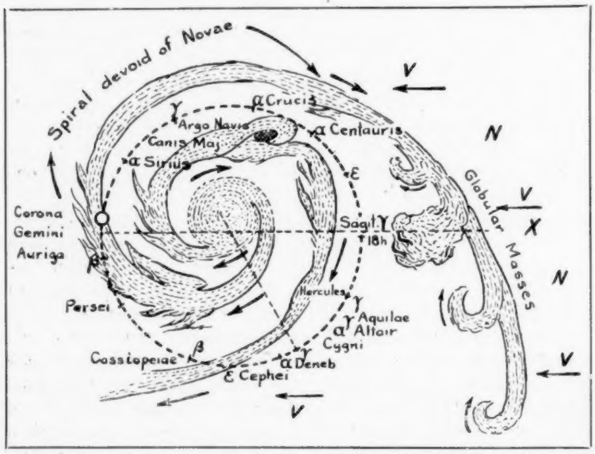

FIG. 8. THE FORM OF THE MILKY WAY IDENTIFIED IN PLAN WITH THE NEBULA OF CANES VENATICI

O nucleus whose radius may possibly be 6,000 years of light; *S* present position of the sun, approximately in the plane of the spirals which appear to be projected one upon the other in representations of the Milky Way.

spiral, and, as a matter of fact, the measurements made by Shapley confirm this view of the ensemble; the distances vary from 20,000 years of light for the nearest, to 220,000 years of light, for the farthest. There is a limited number of the globular masses (86) just as there is of the large planets (8) and for the same reason, since they represent nuclei of periodic condensation—in a word the globular masses are the planets of the Milky Way.

Kapteyn's Currents of Stars and the History of the Proto-sun.—The fecundity of our hypothesis enables us finally to attack the problem of the history of the proto-sun (of the primal sun which projected the planetary sheets) and likewise, the two stellar currents of Kapteyn. We know, in fact, that the stars are distributed in two streams, one of which is directed toward Sagittarius while the other is diametrically opposite.

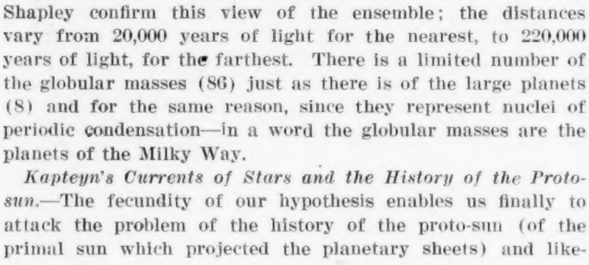

FIG. 9. DIAGRAM OF THE FORMATION OF THE CLOSED GLOBULAR MASSES G AND THE OPEN GLOBULAR MASSES O' AND OF THE STREAMS OF STARS I AND II

The numbers are inverted upon the figure P parabolic trajectory of the proto-sun and S of the sun after it has undergone in the spiral O' the impact which has given it its planetary cortège

Let us imagine, now, the immense gaseous primal nucleus of our stellar universe, whose radius may have been 300 million times the distance of the sun from the earth (Fig. 9). It revolves in the direction of the hands of a watch with its axis perpendicular to the figure. In its shock upon the nebula of our universe coming from the side X (Sagittarius) it bespatters space with two spirals composed of a dust of proto-suns: our own follows the external spiral and arrives after billions of years in the region where are now found the globular masses 1, 2, 3, 4, 5, etc. These are not formed at the expense of the spiral but by the new encounter with the universal nebula, but this encounter makes a selection among the masses: in the path of the globular masses there are found at P the smallest masses of proto-suns, exactly as in the track of Jupiter and of Mars we find the small planets of their family (Fig. 1). Our proto-sun has a small mass in comparison with the other stars; it would be precipitated by the velocity V of P to the point P' upon a parabolic orbit directed toward the nucleus of the Milky Way. It will there encounter at a given moment the internal spiral (Fig. 9) where are found the smallest masses known as the *open masses* O', accompanied without doubt by nebular matter. The shock of our proto-sun upon this matter will produce the *solar Nova*, i.e., the projection of the planetary sheets by means

NEBULOUS MASSES IN THE PLEIADES

of which, according to the dualist theory, our system was formed. At the same time the velocity of the proto-sun which was, thanks to V, several thousand miles per second, will be reduced to a velocity which will correspond to the central attraction of the nucleus O. Continuing its parabolic course our system will wind around this nucleus in order to arrive at S, the tangent to its trajectory now being directed toward Vega and its velocity being 20 km. per second in this direction. We see clearly that we are surrounded with stars all directed toward Sagittarius, like the sun (current II) and stars with circular orbits which follow the opposite direction by reason of the fact that they form a part of the original nucleus of the Milky Way (current I).

EVOLUTION OF THE ARCHITECTURE OF THE SIDEREAL SYSTEMS

Arriving at the terminus of our cosmic expedition it is proper now to define its various stages and present a résumé of the evolution of sidereal systems. In the beginning the enormous velocities of matter which had but slight density and was very widely distributed, prevented the force of gravitation from playing any appreciable part in the evolution of sidereal systems.

The Cartesian Phase.—This was a phase of sidereal systems which is not yet ended so far as the slow evolution of spiral

nebulæ is concerned: It is characterized by shocks between gaseous masses having a high velocity, as a consequence of which immense vortices are produced as was divined by Descartes, thus determining the geometric form of the system. These shocks converting into heat the enormous kinetic force of the proto-suns assure to them a supply of radiation stored in their immeasurable depths and capable of reheating planetary life for many hundred million years.

But the successive shocks have now diminished the cosmic velocities, occasioned concentrations of matter, and almost emptied space of dispersed nebular matter. Hereupon the force of gravitation resumes its sway and reigns as sovereign mistress over the stars traveling in the sidereal vacuum.

The Newtonian Phase.—This is the phase of the sidereal systems characterized by their relative stability and slow velocities, to which the disciples of Newton would fain reduce all celestial mechanics, and in which it is possible to predict phenomena only by the most laborious calculations. The Cartesian phase, on the contrary, was characterized by shocks which can be measured and weighed, so to speak, by the methods of experiment in physics and in mechanics which are current practice in our laboratories.

To a French engineer it has been given in studying the cosmic dramas of the origin of worlds, to construct the first chapter of a new celestial mechanics, which will revive in our country the vortical theory of our great Descartes.

What Are the Nebulae?*

A Name Applied to Three Distinct Classes of Heavenly Objects

By Russell Sullivan

As we cast our eyes toward the skies on a clear night we see a few thousand stars apparently scattered at random over the dark vault of the heavens. We little realize that among these stars are thousands of nebulæ (or little clouds of light), for the most part invisible to the unaided eye and in many cases beyond the reach of all but the most powerful telescopes.

Modern astronomers divide the nebulæ into three classes—extended, planetary and spiral. The first class is well represented by the Trifid nebula in Sagittarius (see page 292). The whole mass is very likely at a high temperature and probably seething with internal movements, although some authorities think that the light is due to a kind of electrical action, similar to the effects observed in comets. The spectograph has shown that these objects are composed of helium, hydrogen and nebulium—the latter element unknown on the earth. Hydrogen tends to separate from the other elements and occupy the outlying portions of the extended nebulæ. Among such objects are to be seen dark nebulæ, i.e., dark or faintly luminous markings which obscure the light of the stars or nebulæ behind them. The dark lanes in the photograph are thought to be non-luminous portions of the nebula or opaque masses which lie between us and the nebula and cut off its light. The region of the Milky Way is crowded with bright and dark nebulæ often merging insensibly into one another. The constitution of the latter is not positively known. Slipher has shown that in one case it is fairly certain that a large, bright nebula, closely allied to a dark object, is not gaseous, i.e., it is probably a cloud of cosmic dust. In this connection it is interesting to note that he has found a few nebulæ whose spectra indicate that they are shining by the reflected light of the brilliant stars in their midst. The extended nebulæ, whether bright or dark, act as a veil and absorb the light of the faint stars behind them; some of the dark nebulæ cover large areas of the sky—others are small and curiously formed. Barnard's observations show that these obscure objects are not confined to the Milky Way, but may be found in other parts of the sky, away from a luminous background and silhouetted against space itself, which glows with an extremely feeble light. The latter conclusion is most remarkable and cannot be explained by any facts known to modern science. The bright extended nebulæ have small average velocities of 6 miles per second, and remain in or near the Milky Way. Their actual size is such that a ray of light would travel many years in crossing from one side to the other. A light-year is the distance that a ray of light (moving at a speed of 186,000 miles per second) travels in one year. The nearest star is about 4 light years from the earth and at this great distance we have hardly begun to sound the depths of the universe. It is generally thought that helium stars (of early spectral type) are formed in these great, irregular masses and the spectrograph has demonstrated the existence of helium stars in the center of the Orion nebula. Reddish stars (of late spectral type) are never associated with the nebulæ. About 150 extended nebulæ (bright and dark) are known. These objects are members of our own stellar system, but are very remote and lie at an average distance of 2,500 light-years.

The planetary nebulæ (so called because they look like the disk of a planet) belong to the second class. High-powered instruments usually disclose a ball and ring structure similar to the planet Saturn. The spectograph in Campbell's hands has taught us a great many things about these strange objects. They are ellipsoidal shells of shining gases, probably at very high temperature, and similar in composition to the bright extended nebulæ. Passing from the nucleus out toward the ring, we find concentric shells of helium, nebulium and hydrogen, in the order named, suggesting the arrangement of gases in the bright irregular nebulæ described above. Campbell and Moore have detected a moderate degree of rotation in these objects, amounting to a few miles per second about an axis at right angles to the plane of the ring, the speed of rotation decreasing as the distance from the center increases. The planetary nebulæ are moving through space at average speeds of 24 miles per second. Campbell has suggested that they are the wrecks of ancient collisions among the stars, but may form in the future solar systems similar to our own. They occupy a volume of space many times the size of our solar system and, like the extended nebulæ, cling closely to the Milky Way or its neighborhood. Each one in its heart holds a star of spectral type (Wolf-Rayet) still earlier than the helium stars in the Orion nebula. From time to time novæ (new stars) have blazed forth in the Milky Way. Shortly after the outburst the majority have become planetary nebulæ and finally have assumed the Wolf-Rayet spectrum. Plaskett has recently found the lines of a planetary nebula in the spectrum of Nova Aquilæ which made its brilliant appearance in the Milky Way June 8, 1918. Barnard has observed Nova Aquilæ in its decline and has actually seen it change into a planetary nebula with a disk of measurable size. These objects belong to our own stellar universe and lie at an average distance of 1,000 light-years. They are comparatively scarce—only 150 have been catalogued to date.

We now come to the largest and most mysterious class of objects—the spiral nebulæ—of which there are several hundred thousand in the sky. Recent researches conducted by Slipher indicate that they are moving at the tremendous average speed of 240 miles per second. They are not, as a rule, seen near the Milky Way, probably because they lie beyond it and are eclipsed by the dark nebulæ; but if we turn our backs to the Milky Way we will be rewarded by finding immense numbers of them. A spiral nebula is flat and may be com-

*Reprinted from *Popular Astronomy*, No. 268.

pared to a pin-wheel or watch-spring—the latter has only one arm, while a spiral nebula usually has two arms joining the center at opposite points. Van Maanen has recently found that the spiral nebula N.G.C. 5,457 in Ursa Major is rotating rapidly about its center. The speed of a particle half way between the center and the edge is in the neighborhood of 200 miles per second, but the nebula is so stupendous that the particle would take 85,000 years to make a complete rotation. Spectographic observations by Slipher and Pease on other objects confirm the high rotational velocities of the spiral nebulæ. H. D. Curtis has recently estimated that the spirals lie at the appalling distance of one million light-years, and this is a minimum estimate. More likely they are from ten million to one hundred million light-years from the earth. The spectograph shows that they are not gaseous, but are composed of stars, star-clusters, and even bright and dark nebulæ. The latter appear as dark bands on photographs of spirals seen edgewise, and suggest the dark nebulæ of the Milky Way. Within the last two years many faint novæ have been found in the spiral nebulæ, thus proving that the spirals and the Milky Way share this phenomenon in common. In the great spiral of Andromeda a new star appears, on the average, every few weeks. These objects are thought to be distant universes or remote Milky Ways, thousands of light-years in diameter, and similar to our own Milky Way, which also shows evidence of spiral structure.

It is now realized that when we use the word *nebula* we mean one of three things, and if we apply it to one class of objects we must logically refrain from using it in regard to the others—so different are these three classes. Thus modern science has taught us to look upon the sky, not as a meager collection of a few thousand stars, but as a universe teeming with vast nebulous clouds, rings and balls, and gigantic pin-wheels.

The Rigidity of the Earth

Measuring Tides in a 500-Foot Pipe by Means of Interferometers

IN 1914 an account was given in the March number of the *Astrophysical Journal* (Chicago) of the experiments made by A. A. Michelson and Henry G. Gale, in the effort to determine the degree of the rigidity of the earth. At that time it was announced that the experiment would be repeated but that the new test would be made by an interference method. The new arrangements were completed and a new series of observations were begun on November 20, 1916, and continued for one year. The reduction of the observations, however, was interrupted by the war and could not be resumed until April, 1919. In December, 1919, the same journal published an account of the result of these new researches. We summarize this account in the following paragraph, omitting the more technical portions.

The same pits and pipes on the grounds of the Yerkes Observatory at Williams Bay, Wisconsin, were used as in the preliminary experiment. In that experiment pipes 502 feet long and 6 inches in diameter were placed 6 feet underground. One pipe was laid accurately N-S and the other E-W. The pipes ended in pits 10 feet deep and 8 feet square, walled with concrete. The pipes were carefully leveled, and half filled with water, so that an air space extended from end to end of each pipe, above the water. The pipes ended in air-tight gages, provided with windows through which the changes in water level could be determined by measuring with microscopes the distance between pointers, just below the surface of the water and their totally reflected images.

In the present experiment interferometers replaced the microscopes and pointers. The arrangement of the interferometers, one at each end of each pipe, is shown in Fig. 1. The compensating glass serves to seal the pipe. The lower mirror is movable vertically and has also the usual adjustments for regulating the width and orientation of the fringes. The film of water over this mirror is kept thin, usually about 0.5 mm. as the viscosity of the water helps to dampen ripples and minor disturbances. The changing thickness of the water film, due to the tides, caused the shift of fringes. The arrangement for recording the fringes was as follows: Horizontal fringes were projected by the lens L on a narrow vertical slit about 0.2 mm. in width. Clock work drew a motion-picture film behind this slit at the rate of about 2 cm. per hour. In order to prevent the condensation of moisture on the optical parts the end of the pipe, interferometer, and camera were all inclosed in a galvanized iron bar, in which large trays of calcium chloride were kept. An incandescent light was continually burning near the interferometer to keep the temperature slightly raised.

Other interference arrangements are obvious which would give a displacement of a greater number of fringes, or permit the use of a shorter pipe; *e.g.*, the fringes formed between the water surface and the lower mirror might be used, or the lower mirror might be dispensed with and use made of the fringes formed by the light reflected from the water and the vertical mirror. But the arrangement actually used was the most satisfactory, since the long pipes, 502 feet, were already installed.

The sources of light were commercial alternating-current Cooper-Hewitt mercury lamps. They proved very reliable and satisfactory. By using as filters thin films of a saturated solution of esculin in water, all wave-lengths from the arc

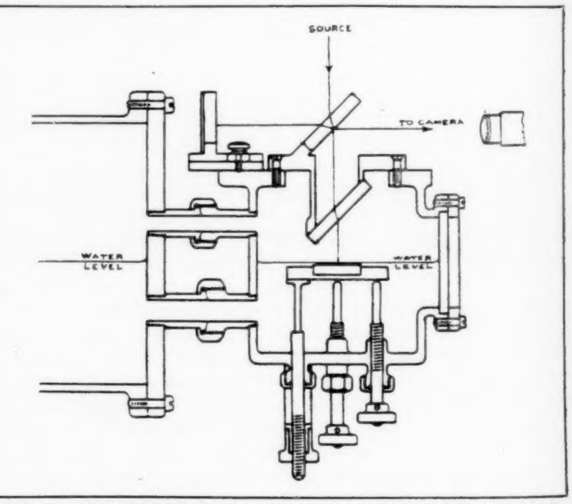

FIG. 1. ARRANGEMENT OF ONE OF THE INTERFEROMETERS

shorter than λ 4,358 were absorbed, and the positive film used was not sensitive to the longer wave-lengths. The exposed portions of the films were removed and developed each week. The light was abundantly strong for satisfactory negatives, and it was possible to use 1.5 mm. diaphragms on the projecting lenses. This gave sufficient sharpness to the fringes, even when there was a considerable change in their focus. It was necessary to readjust and refocus the fringes in only one pit during the entire year, although the width of the fringes was altered once or twice in two other pits. One of the mirrors required resilvering. One of the pits ran throughout the year without readjustment of the fringes or camera. The pits and cameras were in charge of Mr. George Monk and Mr. Frank Sullivan of the Yerkes Observatory staff.

A relay which moved a shutter in front of the projecting

lens was placed in each pit. The four relays were connected in series with a clock in the observatory, so that the time could be conveniently and accurately controlled. Once an hour the clock made contact, and a storage-battery circuit was closed through the relays and the light was cut off by the shutters for about 20 seconds. Very accurate time-marks were secured in this way. The control clock was kept six minutes faster than Central Standard Time in order to simplify the computations and bring the observations into agreement with them. (The longitude of Yerkes Observatory from Greenwich is 5h54m13s.)

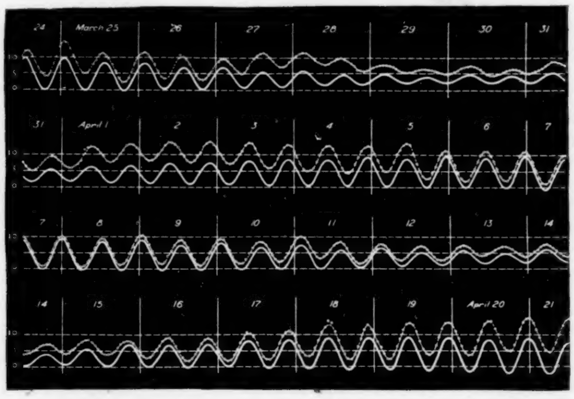

FIG. 2. NORTH-SOUTH TIDES, MARCH 25 TO APRIL 21, 1917
Dotted curves, observed values; full curves, 0.7 of calculated values.

The films were measured by sliding them on a lathe-bed beneath a low-powered microscope. The fringes, estimated to tenths, were counted as they moved up and down, and the numbers recorded for each hour. The difference in the motion at the two ends of each pipe gave the numbers for plotting the observed tides.

The calculated tides were drawn from the computed shift in fringes, the calculations being made for two-hour intervals. The calculations were made under the direction of Prof. F. R. Moulton by Mr. Albert Barnett and Mr. Horace Olsen. The formulæ are given in the accompanying article by Professor Moulton, "Theory of Tides in Pipes on a Rigid Earth." The value of μ for the water used was found to be 1.3408 for λ 4358, and this is probably correct to within considerably less than 0.1 per cent for the range of temperatures used.

Calculated and observed curves for the period from March 24 to April 21, 1917, are reproduced in Figs. 2 and 3. The dotted curve represents the observed and the full curve (displaced vertically to avoid overlapping) 0.7 of the calculated values of the tides. The ordinate are numbers of fringes, $N = \frac{2(\mu - 7)d}{\lambda}$, and one fringe corresponds to 1/1564 mm.

The observed and calculated curves were plotted on long rolls of coördinate paper to the following scale: abscissae, 1 cm. = 1 hour; ordinates, 1 cm. = 2 fringes. In order to have the amplitudes equal, 0.7 of the calculated values were plotted instead of the full amplitudes. Beginning with 10 A. M., November 20, 1916, the curves, both observed and calculated, were divided into periods of 12h.42 for the semi-diurnal and 25h.82 for the diurnal lunar tides. The principal solar tide, period twelve hours, was started at noon of the same day. In order to avoid a cumulative error in the case of the semi-diurnal lunar tide the period 12h.4206013 was put on a computing machine and added repeatedly to the initial time to get the exact beginning of each new period throughout the year. This process was repeated, using the period 25h.8193409 for the diurnal lunar tide.

The observations were reduced in groups of about a lunar month each, by dividing each period into ten equal parts (twelve in the case of the solar tide), and taking the mean of the first, second, third, etc., ordinates. The resulting values were plotted and any error in computation was usually indicated by the failure of a point to fall on a smooth curve. It is important to treat the observed and calculated tides both in the same way, as any distortion in the resulting sine curves due to lack of complete elimination of other periods affects the two alike. This is, of course, most noticeable in the case of the diurnal tide on account of its smaller amplitude and the smaller number of periods. Mr. Fred Pearson gave valuable assistance in measuring the films, in plotting the curves, and in deducing the various tides from the curves.

Very little trouble was caused by sudden erratic changes in the fringes. Occasionally, however, earthquakes would cause the fringes to disappear for from ten minutes to half an hour. Once the effects of an earthquake were evident for about six hours. During three hours of this time the fringes were completely obliterated.

The most serious disturbance was a gradual change in the slope of the observed curves. This would often be fairly uniform and gradual for a month or two. Sometimes the curves would rise and at others fall. Sometimes the N-S and E-W slopes had the same sign, and sometimes the opposite signs. We have been able to discover nothing systematic about this drifting. It may have been caused by unequal settling at the ends of the pipes, by temperature changes in the pits, or by tilting in the earth's strata. There were always large shifts of the fringes when the lights came on after having been interrupted by the power company for half an hour or so.

The final result indicates that the rigidity of the earth in the N-S and E-W directions is the same[1] and the ratio R is 0.690 with a probable error of = 0.004. That the viscous yielding of the earth is small is indicated by the small difference in phase between the observed and computed tides. It will be noted that the two solar tides appear to agree excellently in phase displacement with the E-W semi-diurnal tide and that for the N-S semi-diurnal, and probably also the E-W diurnal lunar tides the phase displacement is definitely smaller.

However, for lack of a better method of finding the means of the N-S and E-W phase displacement, each was averaged as the ratios were, that is, simply by weighing them in proportion to the amplitudes of the tides. This gives a displacement in phase of the water tides in the N-S direction of $+2°41'$ and in the E-W direction $+ 4°34'$. Although it seems certain that the difference in phase is slightly larger in the E-W than

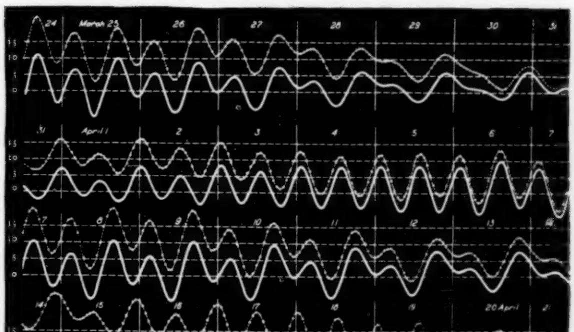

FIG.3. EAST-WEST TIDES, MARCH 25 TO APRIL 21, 1917

in the N-S direction, a mean displacement of $+ 4°.0$ is probably correct to within 1°. If we take R = 0.690, the tides in the actual earth are 0.310 of what they would be if the earth were fluid, and the value of $\Delta\,\phi$ equal to 4.°0, for the displacement of the water tides means that the earth tides lag behind the impressed forces by this same amount.

[1]The preliminary experiment, through an error in computation, indicated a difference in the rigidities in the two directions. This ratio should have been 0.710 for both the N-S and E-W. See *Science*, Oct. 3, 1919, p. 327.

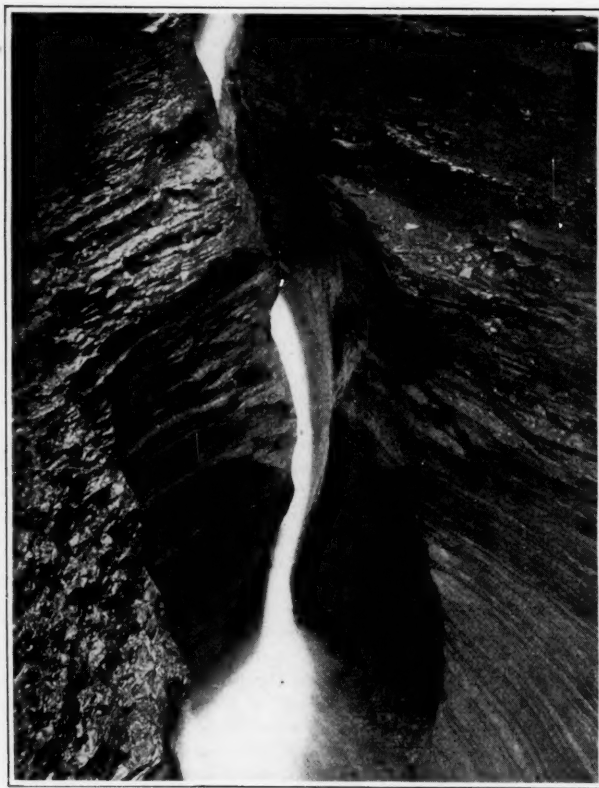

FIG. 1. WATKINS GLEN. FLUME-LIKE CLEFT RESULTING FROM CUTTING OF NORMAL VOLUME OF STREAM ON ROCK OF UNIFORM RESISTANCE

In the foreground may be seen a typical pothole

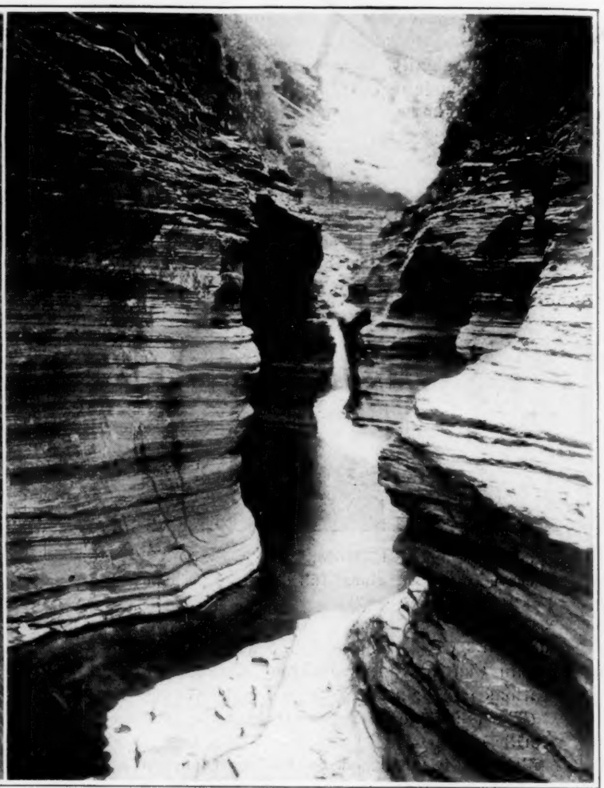

FIG. 2. WATKINS GLEN. A SERIES OF INTERSECTED POTHOLES ILLUSTRATING THE PART THEIR DEVELOPMENT HAS IN THE EXCAVATION OF GORGES

At the top the gorge has been widened by weathering

The Fascination of Waterfalls and Gorges

A Study of Pothole Grinding and Sluice Cutting in the Finger Lakes Region of New York

By O. D. von Engeln, Ph.D.

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MOST Americans, apparently, when in the vacation mood, turn instinctively to some place associated with waterfalls and gorges. It is only on such a basis that the whole-nation popularizing of Niagara, the Yosemite, the Grand Canyon of the Colorado and of the Yellowstone can be accounted for. Thus, anyone who takes the trouble to make even random inquiries will quickly learn that, even in the less obvious instance of the Yellowstone, although the tourist crowd is attracted there by the geyser marvel, it actually finds the Yellowstone Falls and Canyon much more pleasing, and these features of the park, rather than the geysers are what the visitors wish to talk about after returning home. Hence it is pertinent to ask: Why do falling waters so much allure mankind?

On due consideration it would appear that the most plausible explanation of the fascination exerted by waterfalls and rapids in gorges is that these phenomena are among the few spectacular manifestations of dynamic Nature. One may, it is true, hunt up a volcano in eruption and so experience a great thrill; the discharge of icebergs from a tidal glacier is also a stupendous and thunderous exhibition of earth energy, as further is the avalanching of snow and rock from mountain sides. An earthquake, a tornado or a desert sandstorm is not, any of them, a manifestation of Nature in motion that one willingly seeks out to witness; thunderstorms we encounter without going away from home. With the exception then of phenomena that may be grouped with falling waters as special cases, these about exhaust the list of ways in which natural energy is dynamically and spectacularly visible. Geysers come under the general classification of falling waters and so do the ocean waves when they break upon the shore. Accordingly, we may conclude that among the relatively few aspects of Nature in motion vouchsafed us, that of rushing water is at once the most frequently encountered and most safe to view. Hence the urge to seek out waterfalls and rapids; and with these we find associated deep gorges and great canyons.

It may perhaps be objected that mountains have an enticement for the vacationist that is equal to that of any waterfall or gorge site. The argument is pertinent, but it should not be forgotten that when the mountains are reached it is, by preference, at a waterfall or gorge occurrence that camp is pitched or that the hotel resort has been located. In any event pilgrimages to such places from the camp or the hotel are sure to be in order. Moreover the fact that the mountains, in other words the high places of the earth's surface, are also particular goals of the holiday seeker, may be adduced as having a bearing on the popularity of waterfalls and gorges. For by far the largest part of all the world's population lives and has its being on the broad low plains' land of the earth. Quite naturally, therefore, these plains' dwellers, when they feel the need of a vacation, desire to look upon new and different scenes; they seek to escape the placidity of wide and

sluggish rivers and of level acres, and to substitute for this monotony of everyday environment white waters and bold cliffs. That the leaping waters and mountain topography go together is not a chance circumstance, for it is only where the altitude above the sea is considerable that descents can be swift, where waterfalls can occur in the stream courses and where the rivers with exceptional erosive activity can carve out gorges faster than weathering can soften the angularity of valley form that the river processes create.

But it is not the chief purpose of this paper to dwell at length upon what, after all, the reader has from the first known to exist, that is, the general lure of waterfalls and gorges. In any event, Robert Southey in his "The Cataract of Lodore" has so completely presented all the obvious elements in poetry that one could scarcely hope to make them more vivid in poor prose.

The fact, on the other hand, that the great numbers of people who visit waterfalls and gorges only do so in response to the more or less instinctive craving already indicated, and that, once there, they marvel at what they see in an uncomprehending way, affords an unpoetical physiographer a quite adequate excuse for attempting these paragraphs. To put the matter succinctly, it is my particular thesis to point out that waterfalls and gorges have each their peculiar characteristics, that these special characteristics are in every different instance due to some variation in the circumstances of their origin and that appreciation of just how this and that peculiarity came to be will add much to the interest of a visit to any of these show places of Nature. Further the study is not a difficult one, and once its elements are grasped the application to the actual site will be easy.

While waterfalls and gorges are found, as has been suggested, in some frequency and degree of development in practically all upland regions, abundant occurrence within any relatively restricted area, coupled with sufficient height and volume, in the case of waterfalls, and of great enough depth and length, in the case of gorges, to be at once interest compelling and imposing is the rule only where a particular and limited set of physiographic factors have been existent and operative in the proper conjunction.

The first essential is that of a region of great enough ele-

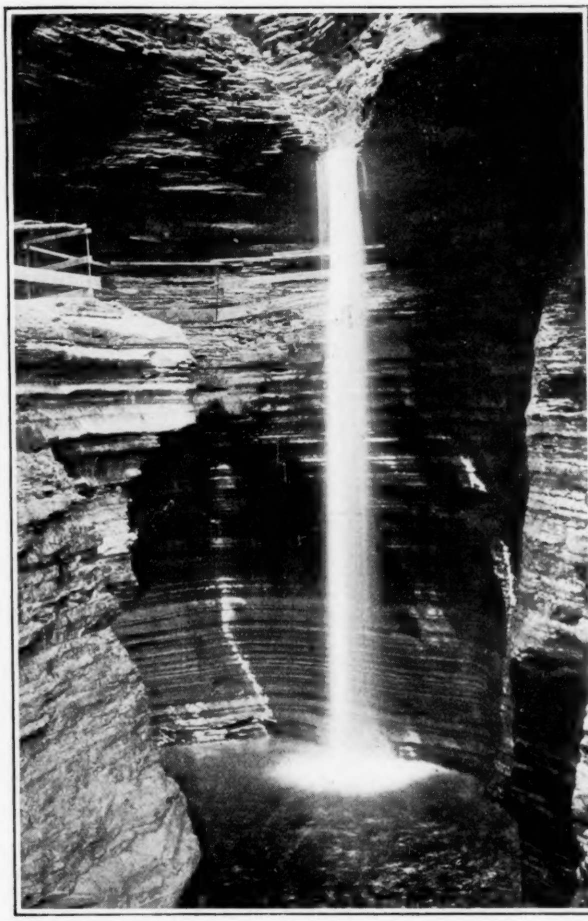

FIG. 3. WATERFALLS DEVELOPED IN LAYERED ROCKS PRIMARILY AS A RESULT OF A PROCESS OF POTHOLE GRINDING AND INTERSECTION

FIG. 4. VIEW OF A SINGLE POTHOLE, SHOWING LOW WATER STAGE, INEFFECTIVE FOR FURTHER ENLARGEMENT

The current suffices for development of flume-like cut which may in time join this pothole with one above

FIG. 5. SERIES OF POTHOLES WHICH HAVE PEEN JOINED UP BY UNDERCUTTING AND BY SLUICE GRINDNG OF THE WATER RIBBON

The gravel bar is due to deposits of rock fragment tools below the zone of swirling motion of the water

vation above the sea to afford the possibility of notable descents in short reaches of a stream course. A second is that the rock material of which the heights are composed should be varied in kind and structure so that the water will not be able to wear down equally fast in all parts of its course. A third is that either the uplift of the area shall have been so recent and rapid that the streams will not have been able to complete their down-cutting, or that, after such cutting had perhaps continued long enough to eliminate waterfalls and gorges some other agency shall have interposed to introduce new discordances of level in the courses of the streams.

It is where sedimentary or layered rocks occur in alternations of sandstones, limestones and shales that notable variations in resistance to erosion are encountered by streams. Granitic types of rocks are apt to be uniform over wide areas hence do not afford streams the opportunity to cut down faster in one part of their courses than another; and it is this condition, fundamentally, that gives rise to waterfalls and gorges. Thus many of the elevated regions of the eastern United States are deficient in waterfalls because they are of one kind of sedimentary rocks, as the Catskills—practically all sandstone, the Adirondacks all granite types. Moreover these and other uplifted regions to the south have been subject to the action of streams for so long a time without interruption that one-time waterfalls and gorges have, in the present physiographic stage of their development, been largely eliminated.

There is however one plateau area near to eastern population centers, the Finger Lakes Region of central New York, where all the postulated conditions for the development of waterfalls are found and where as a result they, and the accompanying gorges, actually occur in such numbers as to afford a great variety of individual variations. Photographs of some of these will serve to illustrate the points to be noted in an interpretative appreciation of such phenomena as has been urged above.

The Finger Lakes Region of central New York is part of the same uplift that is in other parts of the country called the Pocono, the Alleghany and Cumberland Mountains. Like these so-called mountains the Finger Lakes Region is made up of alternating layers of sandstones, shales and limestones and was subject to a long period of erosion in an earlier age. But while down-cutting has continued without interruption in the case of the last three regions named, the Finger Lakes Region was subjected to glacial action during the time when immense glaciers from the north covered all the northern part of the United States. A notable effect of such glaciation was the great overdeepening of many of the main valleys while tributary valleys were scoured out little if at all. A first result of the overdeepening, particularly of the north-south valleys that were in the direct line of ice motion was the creation of a number of long and narrow lake-basins from which the region derives its "Finger Lakes" name; lakes which add an element of great charm to its broader landscapes. A second effect was to leave most of the side or tributary valleys with their rock floors terminating far above the levels of the lakes, "hanging valleys" in the language of the physiographer. Accordingly, immediately after the ice had melted off, there must have been many waterfalls leaping directly from the lips of such hanging valleys into the lakes. But long enough time has elapsed since that event for the streams to have cut deep gorges, back from the lake troughs, and it is in these gorges that the waterfalls of today occur and they, and the gorges themselves, owe their particular characteristics, in each instance, to the nature of the variation in rock structure that the several streams encountered in their making.

FIG. 6. LOWER PART OF LUCIFER FALLS IN ENFIELD GLEN

Note the cascading effect due to the joint plane system. The smooth rock faces are due to the joint fissures extending across the face of the falls from the right

It will, perhaps, serve the purpose of an interpretative study best to begin with a consideration of the special features exhibited in Watkins Glen, primarily because the general factors involved are there presented in simplest form for an introduction to the appreciative understanding that we seek; also because Watkins Glen is quite well known to tourists and has in recent years been made a public park by the State of New York and provided with facilities, in the nature of stairways and paths, to make all its length easily accessible.

The first illustration (Fig. 1) brings out very clearly the several elements that are responsible for the characteristic features of Watkins as distinguished from other gorges in the region. It will be noted that the rock layers through the whole vertical range that appears in the picture, are very uniform in kind, and thin-bedded. This is true of practically the whole gorge. In consequence, the water, which was, at the time the picture was taken, at about the normal volume of flow, will be observed to have cut a narrow flume-like channel. The stream had, from the end of the glacial period, a steep descent, it was furnished with ample amounts of sand and gravel to serve as scouring tools, it flows usually about this much volume, the rocks are of very uniform consistency; hence the flume-like channel that has been carved. The slight, "stretched-corkscrew" twist of this channel is presumably inherited from the original departures of the stream from a straight line course, accentuated by alternation in concentration of the force of the current, first on one side then the other of the channel, while the rock cutting was being done.

FIG. 7. JOINT PLANE GUIDANCE OF STREAM WITH A RIGHT-ANGLED TURN
Note the rectangular block of rock pried loose and temporarily lodged in the narrow channel. This illustrates how the stream erodes such a channel. See also Fig. 8

The circular cavity in the foreground of the picture illustrates a typical *pothole* development. While potholes are recognized at sight by the average tourist it is a curious fact that their important relation to the general process of gorge formation has not been sufficiently noted by scientific observers. It would seem that a very large proportion of all the solid rock, excavated by stream action in the making of many gorges, has been removed as the result of pothole grinding. Certainly this has been the case in certain sections of the Watkins Glen, as will, for example, be apparent from a simple inspection of the second picture (Fig. 2).

Any slight irregularity in the bottom of a stream, as it flows over a horizontal bedrock surface, will suffice to initiate a swirl in the water current. In consequence of this swirl sand particles that are being swept along the bottom will have imparted to them a gyratory motion and the localized grinding action that this occasions shortly brings about the development of a cup-like hollow. In this hollow pebbles and bits of gravel are apt to lodge. The normal current may be sufficiently strong to swirl these pebbles as well as the sand, but not to lift them out of the depression. Thus the circular grinding is accelerated, and the incipient pothole is made deeper. At the same time the bottom is always maintained as the widest part, because, within certain limits, as the pothole is deepened the circular erosion, acting to widen the depression, becomes increasingly effective; since the whole of the normal stream current is eventually involved. If, next, it will be conceived that a series of potholes are started, at rather closely spaced intervals in the length of the stream course, it will be evident that in time the bottoms of adjacent potholes will be made to intersect each other, permitting the flow of the water from out of the upper into the next lower pothole without needing to "boil" over the top. Under such circumstances one might except that a small natural bridge would develop, and such a phenomenon has actually been observed. Ordinarily, however, the rush of flood waters quickly effaces the narrow rock barrier remaining and the conditions shown in Fig. 2 result.

Note how clearly the rocks at the left of Fig. 2 continue to show the circular grinding action characteristic of pothole development, though the potholes have intersected for some time. The little differences in rock resistance of the thin layers and their dividing planes have brought about a very detailed fluting. Consider, further, how much of the channel width is due to the pothole excavation, as are also the peculiar rock forms the channel exhibits. Finally note the contrast between the smoothed rock surfaces in the lower levels and the weather-roughened edges of the layers at the top and the change in form of the gorge section marked by the line of separation of these two effects. From this single view it will be very clear how gorges in humid regions are, in time, widened out by the frost, decay and solution processes of weathering.

Figs. 4 and 5 are "close up" views of other potholes in the Watkins Gorge, the former of a single hole in what is probably its near maximum stage of development. The water current at this period of low flow is not effective in excavating

this pothole further, only at times of high water can more grinding be done here. The small current shown is, however, meanwhile filing down a narrow sluiceway like that in Fig. 1 above the pothole, and such action may, in time, suffice to join up this pothole with one above, and such a development is suggested by Fig. 5. The gravel bar in the foreground of this picture is interesting in that it shows how the rock-fragment tools that accomplish the pot-hole grinding are deposited by the slower current below the zone of swirling motion.

Once initiated, potholes very quickly attain sufficient width to involve the whole flow of the stream, as is very clearly apparent from the several pictures already considered. The normal pothole grinding is partly responsible for this but it seems that it is only where potholes occur in stream courses with a steep descent, over rock masses of uniform structure, and develop in series that their excavation actually determines gorge characteristics. Under such circumstances the farthest downstream member of a pothole series will, in time, have its lower wall deeply breached by the sluice grinding, illustrated in Figs. 1 and 5, so that, in consequence of the lowering of the water level in it, as a result of the breaching a small waterfall will develop at its upper side. The effect of the creation of the waterfall will be to accelerate greatly the deepening of that pothole, for the whole current of the stream will now be involved, and the force of the entering current much enhanced by its vertical plunge. In fact large potholes are quite generally *plunge-pool* developments. As the breaching of the lower side of the pool continues the fall necessarily becomes higher and excavation at the bottom of the pothole is further accelerated. In time, however, the barrier between the lowest pothole and its neighbor next upstream is cut through to a considerable depth, and then part of the plunge-pool acceleration of excavation is transferred to this next-upstream hole; for a waterfall will be created at its upstream side at the expense of the height of the waterfall into the lowest pothole. If, then, the rock barrier between the lowest pothole and its next-upstream neighbor is narrow the widening of the second pothole, now going on apace, may very quickly cut this separating rock dam almost completely away, and the two potholes will intersect. These effects are extended to the whole series of potholes, and the gorge acquires its distinguishing characteristics as a result. The process, as set forth in words, may seem rather complicated but so many phases of its progress are illustrated by the four Watkins pictures that its application will be quite clear.

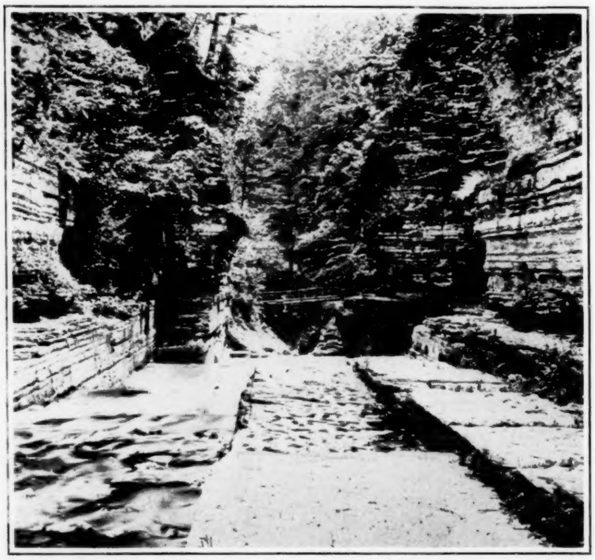

FIG. 8. UPPER ENFIELD GLEN SHOWING THE REMARKABLY STRAIGHT AND ARTIFICIAL-APPEARING WALLS AND CHANNEL DUE TO EROSION GUIDED AND DETERMINED BY RECTANGULAR JOINT PLANE FISSURING

The farthest upstream member of the pothole series will be the last one to be affected by the breaching and intersection process. Accordingly, it will have the longest time of any in the series to develop and, as the rock mass upstream is continuous, there will be no breaking down of its upper wall by intersection. Its waterfall height will only diminish therefore as the slower sluice-grinding process cuts a groove. On the other hand, the lower members of the pothole series may, in the meanwhile, become almost completely joined and thus the total depth of their excavation is eventually measured in the plunge of the single waterfall into the head member of the pothole series. Thus a waterfall of quite respectable height is created, simply by a process of pothole grinding and intersection.

Such a result has been achieved in Watkins Glen at the point shown in Fig. 3.

Note that, in the section above the level of the walk, weathering, particularly frost action, due to spray from the falls, is doing its part in widening out the cavity. In other words, the pothole excavation is here supplemented by a typical waterfall process in the opening out of an amphi-

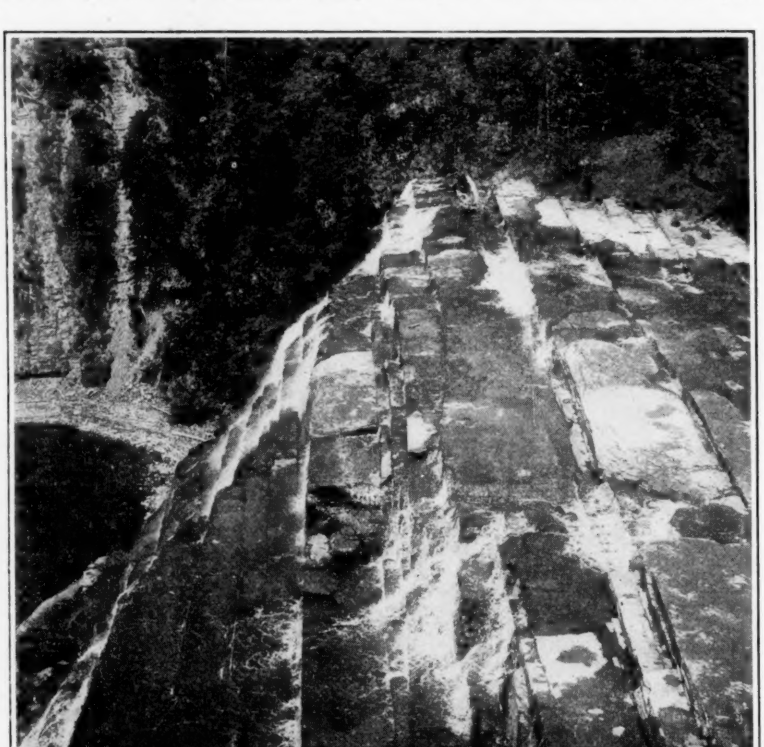

FIG. 9. ITHACA FALLS, SHOWING THE VERY STRIKING STAIR-STEP EFFECT DUE TO SUCCESSIVE QUARRYING OUT BY THE STREAM OF PRISMATIC BLOCKS OF ROCK

theater-like section in the gorge below the point of occurrence.

Though such a conclusion would need to be confirmed by a much more extended series of observations than the writer has had opportunity to make, it is not improbable that waterfalls of significant size can be developed only by intervention of the pothole grinding process, as described above, in areas where the bedrock is of uniform resistance through all the vertical range involved in the descent of the stream course. If such interpretation is correct then in it may, perhaps, be found the clue to the occurrence of the highest single falls in the Finger Lakes Region, that of the Taughannock Falls, in a gorge of the same name that opens into Cayuga Lake from the west. Though readily accessible by railroad and hard road, this gorge and falls are not nearly so well known as Watkins; yet they are quite as interesting and more impressive. Very few places in the United States east of the Rockies afford the spectacle of a gorge with vertical rock cliffs, over 300 feet high and a waterfall with 215 feet straight drop from crest to pool. What is more surprising is that this gorge and falls have developed in very fragile shale rock. As will be noted in the frontispiece there is no variation in the structure of the rock at the brink of the falls that might account for their presence as the result of difference in rock resistance to stream erosion above and below the cataract. Moreover the gorge walls below the falls are nearly vertical for quite a distance downstream. Since the rock material is so little resistant as to be easily worn and weathered the existence of these high, steep walls proves that the gorge must have been excavated very rapidly. This fact and the uniformity of the rock suggest the origin of these great falls to be due to pothole grinding, the evidence of which has, however, now been effaced; the development of the gorge at present being due to the enlargement and recession of the amphitheater below the falls as a result of plunge-pool undercutting, coupled with solution and frost action; accentuated at this point because of the large volume of spray from the hurtling waters. The abundant occurrence here of vertical fissures, joint planes, dividing the rock into block-like masses, and giving rise to the very smooth rock faces at either side of the gorge, near the level of the crest of the falls, may have been a significant factor also in the origin of Taughannock.

But Taughannock Falls is admittedly something of a puzzle, an occurrence that the amateur interpreter of gorges and falls is not apt to encounter. By far the larger number of all waterfalls and cascades owe their existence to the presence of rock materials of markedly different resistance to erosion in the courses of streams having relatively steep descents. Niagara is the type example of such a development, and, while Niagara itself is some distance outside the Finger Lakes Region of New York, there are, in the latter area, many falls and gorges of essentially the same origin and characteristics; if less magnificent than Niagara then at least much more picturesque. Such, for instance, is the example illustrated in Fig. 10, a falls found in Enfield Glen. It will be noted that the level of the crest of the falls is marked at the right by a layer of more durable rock than the average of the section and, further, that while this, relatively thin, durable layer has been notched (on the right) by the sluice grinding of the stream another, thicker, durable layer, a little way down from the top, is resisting much more successfully and the water makes a new leap from the level of the shelf this layer forms in the face of the falls.

FIG. 10. A PICTURESQUE FALLS IN ENFIELD GLEN

Note the more durable layers of rock at the crest of the falls and a little below. Note also the notching of the right side of the brink of the falls by sluice grinding of the thin layer of comparatively soft rock.

The history of this most common type of waterfall is very simple. A stream with steep descent deepens its channel by wearing away the bottom. If in the course of this process it encounters a mass of rock more durable than the average, the rate of down cutting is slowed up at that point in the course. At first such checking at one point will not affect the rate of wearing down, either above or below the point of encounter. But if the resistant layer, or mass, is sufficiently durable to persist for some time, yielding, comparatively, very little to wear, then all the less resistant material, upstream from the point of first encounter will be excavated down to the level of the top of the durable material; but no lower, for this level will mark, for the time being, the limit of downcutting possible. Accordingly there will develop upstream from the point of encounter a gently-sloped course, only sufficiently steep to permit of the flow of the water in transporting its sediment load. But the stream below the point of encounter with the durable mass is not so handicapped in its downcutting activity, and rapidly excavates the less resistant material there found. Thus a markedly steeper declivity is very quickly created below the point of emergence of the durable rock and the increased velocity of the water over this declivity further accelerates the erosion.

As soon as even a short vertical fall is established a plunge-pool will begin to be hollowed out at its base and the effectiveness of the downcutting of the stream course below the fall much increased by this type of pothole development. Moreover, in the case of horizontally layered rocks or layered rocks inclined slightly upstream, the undercutting, resulting from the plunge-pool excavation will cause the crest of the falls to recede upstream by undermining the resistant layer to such an extent that pieces of it must drop off from time to time. The eventual effect of this process will be the developing of a steep-walled gorge section in the course of the stream, the origin of which may be betrayed by remnants in its bottom of the series of plunge-pools that contributed to its making and were successively abandoned as the falls moved upstream. If the layered rocks of different resistance incline down stream, the more durable ones will bring about the formation of rapids with a slope downstream as steep as the

inclination of the resistant layer. If the fall-creating rock extends as a vertical barrier across the stream course then the waterfall will always remain at the point where it was first formed; the gorge below will first attain the maximum depth permitted by the conditions of the stream course below the point of the fall occurrence, and then, as time goes on, the falls will be gradually reduced in height because of the slow wearing down of the top edge of the resistant barrier.

Enfield Glen is not even so well known as Taughannock Gorge, and much less so than Watkins Glen, although in many respects more attractive than either of these. The lesser fame of Enfield is due to the fact that, until recently, it has been with difficulty accessible. Within the past few years, however, a State road has been built to within a quarter mile of its head and the gorge itself has been provided with paths and bridges and presented to the State of New York for a public park by the former owner, Mr. R. H. Treman, recently Deputy Governor of the Federal Reserve Bank of New York City. As this new State park lies only a short distance off the shortest route of motor travel over macadam highways between Buffalo and New York City it is quite probable that Enfield Glen will be visited by a much greater number of tourists in the near future.

A stop at Enfield Glen will be repaid first by the sight of the cascading waterfall shown in Fig. 6. This fall has a total height of over 200 feet, much higher than any in Watkins, and possessed by a setting of extraordinary natural beauty. The rocks in Enfield also differ from those at Watkins in that they vary in resistance sufficiently to give rise to a number of smaller falls of the same type as this largest cascade. But the particular interest of Enfield is the gorge itself, for this shows, most remarkably, the effect of evenly and strongly developed *joints* on the guidance of a stream course, as illustrated in Figs. 7 and 8. The very artificial appearing, straight-walled reaches that appear in these pictures, the remarkably sharp, right-angled turn in the course of the stream and the uniformity in width of the channels are all three features due to the presence of an evenly spaced, uniformly developed and persistent system of joint planes, or vertical fissures extending through the rocks at right angles to each other and, as it happens, oriented very nearly with the cardinal directions. In times of high water the force of the water, on occasion, is sufficiently great to pry and push loose the angular blocks of rock because of their separation by the joint planes and once detached from their foundation these blocks are shoved along until they are battered to pieces or perhaps toppled over the edge of one of the falls and broken into fragments.

Enfield Glen is remarkable, therefore, because of the exceptional degree in which the single factor of the joint plane system of the rock structure there has been a dominant feature in determining its particular characteristics. The effect of thick masses of rock, essentially of one kind, in governing the nature of gorge erosion has been noted as the particular feature of Watkins Glen, and Watkins therefore illustrates the simplest case. Differences in resistance of the rock material encountered by the stream in its downcutting result primarily in the development of falls and rapids. The third factor, the jointing of the rocks, accordingly as it is markedly or only slightly, regularly or irregularly developed, affects both the general form of a gorge and its particular features.

Thus while the differences in resistance of the different layers of rock in Enfield Glen have been sufficient in degree to make for the initiation and preservation of waterfalls of considerable height, as a consequence of the stream's erosive action, the joint planes have determined the particular form of these falls. The outline of the crest of Lucifer Falls for instance is determined by a resistant layer that forms a right-angled projection, and this projection is due to the fact that each of its sides is the result of a line of cleavage due to a joint plane. The block of rock now at the edge is cut off from the rest of the bedrock upstream by other joint fissures parallel to those of the crest, and, in time, when undercutting at the front of the falls has sufficiently undermined this block, it will crash down and the falls will then suddenly pour through the corner of a reëntrant angle as is at present the case with Taughannock Falls. About thirty years ago Taughannock Falls had a projecting edge like that which Lucifer Falls has today. The Taughannock change was not as sudden or as marked as that of Lucifer Falls in Enfield Glen is likely to be, for, as will be noted in the picture of Taughannock, the jointing of the rock there is quite closely spaced and the rock itself does not vary greatly in resistance over the whole vertical range marked by the height of the falls.

It would be interesting to introduce here a number of illustrations to give some idea of the great variation in form of falls and gorges that is ascribable to differences in the joint system of the bedrock masses involved. But one more instance must suffice, all the rest will provide the interested reader with an opportunity for personal observation and elucidation at the sites where encountered. Fig. 9 is a view looking down on the top of Ithaca Falls in Fall Creek, adjacent to the Cornell University campus. Here the set of joints that are parallel to the crest of the falls is strikingly developed and, in conjunction with the horizontal planes of the layering of the rock, have brought about the removal of the rock in rectangular prisms of considerable length. Hence there has developed the quite unique stair form that the top of this falls presents.

In conclusion, while hoping that this analysis of the factors that are involved in the development of gorges will provide readers with a basis for their appreciation somewhat more discriminating than that on which the lure of such phenomena for the average tourist depends, it may not be amiss to add a word of caution. Do not, in the enthusiasm for visting waterfall and gorge sites that these lines may engender, permit yourself, if you are an unmarried feminine person, to get into the predicament of one girl who had sought out Watkins Glen. After seeing its wonders she exclaimed tragically, "Now I can't get married; I've been to Niagara and to the Yosemite and here I am at Watkins; there's now no place left to go to on a wedding trip!"

DEVELOPING NIAGARA FALLS WITHOUT MARRING ITS BEAUTY

ALTHOUGH the Horseshoe Falls discharge sixteen times as much water as the American Falls and have a crest line two and six-tenths times as long, yet they are often held to be inferior as a spectacle to the lesser American Falls. The crest line forms a deep curve which makes it impossible to see more than about one-half of these falls at a time except from one viewpoint in Canada. In the central 1,000 ft. (300 m.) of the crest line, situated deep in the curve, more than 80 per cent of the flow over the falls plunges down over the cliff behind a thick cloud of mist. Perhaps more than one-half of the water flowing over this cataract adds nothing at all to its grandeur. The ends of the crest line are never well covered with water and frequently are bare. One remedy would be to construct a submerged dam or weir in the center of the rapids just above the crest of Horseshoe Falls. This would spread the water away from the center to the ends. With this done the inequality of flow over the two falls could be partly remedied without detriment to the Canadian Falls by forming a low submerged weir between the upper end of Goat Island and the Canadian shore.

If these remedial works are provided, it is believed that a total diversion of 80,000 sec.-ft. (2,240 cu.m. per second) may be made around the falls and 40,000 cu.ft. (1,120 cu.m.) per second around the Whirlpool and Lower Rapids without injury to the scenic beauty.—Abstract from an article by Col. J. G. Warren in the *Electrical World*, Aug. 14, 1920.

Some Future Problems of Chemistry

Inventory of Our Natural Resources and the Coming of the Aluminum Age

By Ingo W. D. Hackh A. B., Ph. D.

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THE two fundamental material sciences, chemistry and physics, are now passing through a far-reaching change which unfolds to man's perception the sub-atomic world. The atoms, the bricks of the material universe, have become firmly established as chemical units and modern science is beginning to dissect them into physical units and enter into the mysteries of their structure. Incident with this opening of a new field of physical and chemical research is the theoretical completion of the system of matter as expressed in the periodic law of the chemical elements. From the completed periodic system[1] it becomes possible to predict that only five more elements between hydrogen with the lowest, and uranium with the highest atomic weight, wait to be discovered,[2] and that the total number of elemental species upon our earth seems to be restricted to ninety-two. Having thus found that only 92 elements or different types of atoms are possible, the next step is the inquiry into their relative importance as shown by their abundance upon the earth surface. From a multitude of analytical data Dr. F. W. Clarke has calculated the average composition of the lithosphere (rocks, minerals and soils), hydrosphere (oceans, lakes, rivers), and atmosphere,[3] and from these data compiled the average composition of the known terrestrial matter, that is, the solid, liquid and gaseous, substances of the earth crust extending to a depth of ten miles into the interior. This inventory proved conclusively that the elements most abundant in nature are always present in living matter, the biosphere,[4] nearly 98 per cent of which constitutes the four elements, carbon, hydrogen, oxygen and nitrogen.

A study of the relative abundance and distribution of chemical elements reveals some interesting facts[5] which may serve as guiding stars in the future evolution of mankind. The far-sighted business man and inventor as well as the statesman and economist will profit by an examination of the problems of science. One of the fundamental problems of applied physics is the utilization and transformation of energy other than that of coal. This has been discussed in a charming way by Professor Soddy in his booklet on "Matter and Energy." The fundamental economic problem of applied chemistry, however, is the efficient utilization of the available materials of the earth. Thus *e.g.* the use of crude oil as fuel has often rightfully been called wasteful, for in burning the oil the storehouse containing treasures for the organic chemist goes up in smoke. The ever growing consumption of iron and steel has led some writers to calculate from the present known resources the day when the supply of iron ores will have been exhausted. True, the present generation need not be alarmed that the bountiful fountain of nature will cease to give forth its useful materials, but it is for the preservation of some future civilization that a lavish consumption of natural resources should be avoided.

A retrospect into man's past evolution gives an aspect of the future. For example the epochs of history have been given the names of the most useful or most used metals. So prehistoric man of the stone-age utilized metallic gold, picked up here and there in the river beds and mountain sides and used this malleable nugget for his primitive needs and chiefly for ornamentation. No further treatment save mechanical skill was necessary in the utilization of this metal. Next in time came the copper age. The metallurgy of copper being relatively simple, for by wood fire alone the proper ores could be transformed into metallic masses and consumed. The scarcity of native copper and suitable copper ores probably led to the addition of other metallic ores and initiated the wonderful bronze age, which flourished in some localities in historic time. Then followed the iron age which required greater technical and chemical skill and led into the present steel age with its complex metallurgy which is a science in itself. Thus from gold through copper to bronze, then to iron and steel, has been the march of civilization; each step requiring more complex and intricate chemical knowledge.

If evolution is the progress from the simple to the complex, then the future age will probably see the rise of aluminum and its alloys. The metallurgy of aluminum is quite complicated, and although in its infancy at present it has prospects of tremendous possibilities. E.g. aluminum alloys practically with every metal and some of these alloys have properties not attained by steel; there are alloys hard and soft, rigid and elastic, tensile, ductile, malleable and nearly all of low specific gravity, some of which are already irreplaceable in the airplane industry. Furthermore, the storehouse of nature contains twice as much aluminum as iron if measured by weight, and nearly four atoms of aluminum for every atom of iron.

The later statement is perhaps best illustrated by the following table which shows the order of distribution of the 25 most abundant elements. In the first column is given the percentage by weight, taken from the calculations of F. W. Clarke[3], but as explained elsewhere[5] the chemical meaning of these numbers are obtained by division with the respective

ABUNDANCE OF CHEMICAL ELEMENTS UPON THE KNOWN EARTH SURFACE

	Abundance by weight		Relative abundance of atoms
1. Oxygen	50.02 %	1. Oxygen	249,850
2. Silicon	25.80 %	2. Hydrogen	75,312
3. Aluminum	7.30 %	3. Silicon	72,860
4. Iron	4.18 %	4. Aluminum	21,528
5. Calcium	3.22 %	5. Sodium	8,200
6. Sodium	2.36 %	6. Magnesium	6,835
7. Potassium	2.28 %	7. Calcium	6,422
8. Magnesium	2.08 %	8. Iron	5,982
9. Hydrogen	.95 %	9. Potassium	4,660
10. Titanium	.43 %	10. Carbon	1,199
11. Chlorine	.20 %	11. Titanium	714
12. Carbon	.18 %	12. Chlorine	451
13. Phosphorus	.11 %	13. Fluorine	421
14. Sulfur	.11 %	14. Phosphorus	283
15. Fluorine	.10 %	15. Sulphur	274
16. Barium	.08 %	16. Nitrogen	171
17. Manganese	.08 %	17. Manganese	116
18. Nitrogen	.03 %	18. Barium	46
19. Chromium	.028 %	19. Chromium	46
20. Strontium	.017 %	20. Nickel	26
21. Nickel	.019 %	21. Vanadium	23
22. Vanadium	.015 %	22. Lithium	22
23. Zirconium	.015 %	23. Strontium	16
24. Lithium	.003 %	24. Zirconium	13
25. Bromine	.001 %	25. Bromine	1
All others	.392 %		
	100.000%		

[1] See also *Scientific American Supplement*, Vol. 87, p. 146, 1919.
[2] *Amer. Journ. of Science*, Vol. 46, p. 481, 1918.
[3] *U. S. Geolog. Survey Bull.*, 616, 1916.
[4] *Journ. General Physiology*, Vol. 1, p. 429, 1919.
[5] See *Science Progress*, Vol. 14, p. 602, April, 1920.

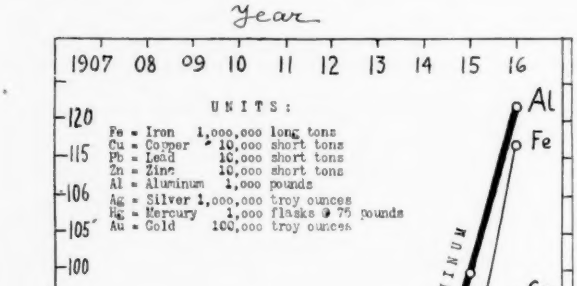
atomic weights. The resulting numbers show, then, the relative abundance of the atoms, and in the second column this atomic abundance is given with regard to one bromine atom. From these numbers it can be deduced that e.g. for each carbon atom there are about 5 iron atoms, 18 aluminum atoms, 208 oxygen atoms, and so on. This table represents an inventory of the terrestrial supply of the most common elements for the total percentage of all other elements is only 0.39 per cent.

Nature's most abundant metal is thus aluminum! The ever increasing importance of this metal can be predicted not only by historical data as outlined above but also by statistical data. Thus in the United States the consumption and production of aluminum increased as follows:

1885	283	pounds	(p)
1890	61,281	"	"
1895	920,000	"	"
1900	7,150,000	"	"
1905	11,347,000	"	(c)
1910	47,734,000	"	"
1915	99,806,000	"	"

(p) = production ⎫ from Mineral Resources of the United
(c) = consumption ⎭ State, 1915, page 167.

The rapid growth of the aluminum industry is further shown in the comparative diagram of the metals industry in the United States in which the aluminum curve for the last ten years is steeper than all other curves and indicates therefore the largest relative growth.



THE RAPID GROWTH OF THE ALUMINUM INDUSTRY

The diagram shows further that *e.g.* the production of gold remained practically stationary, silver a steady increase, mercury a periodic slow increase, copper and zinc since 1914 a rapid increase, caused by the war activity, and finally iron ore and pig iron a periodic and steady increase. All of these curves are however overshaded by the rapid rise of the aluminum production! The ever growing importance of aluminum thus established, it remains for the inventive genius to devise more economic methods of production. Practically all aluminum of today is made electrolytically from bauxite, but there is the great possibility of extracting metallic aluminum from the abundant silicate rocks, such as feldspar, leucite, and sericite. Some of these processes yielding potash and sodium salts in addition to alumina have already been patented. For successful economic exploitation of such processes there is, however, much work for the inventive chemist.

Another element with a prominent future will be silicon, which is next to oxygen the most abundant element. As a cousin to carbon it has similar properties and considering the complexity and galaxy of carbon compounds what untold riches may be expected from the chemistry of silicon compounds! Industry has hardly begun to draw on its possibilities and yet it has already become indispensable in many ways. Silica or quartz (SiO_2) is used in a number of ways in the manufacture of various products; silica utensils are the ideal material for chemical and physical instruments. Waterglass is likewise extensively used in industry for various purposes. Carborundum is next to the diamond the hardest substance. But the development of the organic silicon industry is still in its infancy and should likewise offer an attractive field of research.

Sodium and potassium are likewise abundant. While their salts are utilized daily in every branch of industry, the free elements are but little used. As they are chemically the most active metals, and physically the most electro-positive substances, their utilization on a large scale should offer advantages. The peculiar photo-electric behavior of these two metals might be utilized by some ingenious inventor for the transformation of sunlight or solar energy into electrical energy—the solution of this problem would revolutionize our civilization and mark a new epoch in physical history.

The next abundant elements are calcium and magnesium. Their alloys with aluminum have the great advantage of lightness, magnalium having a lower specific gravity than either aluminum or magnesium. The industrial development of these alloys will prove beneficial to the automobile and airplane industry. At present metallic magnesium is but little used. During the war it served in aerial bombs and rockets to light up the country at night, and as constituents of shells to indicate the location of bursting shells by their white smoke. A small quantity is used for flashlight and in the chemical laboratory. But the properties of metallic magnesium as a deoxidizing agent should be utilized to a much larger extent in industry. Metallic calcium is practically unused, yet its chemical and physical properties are bound to secure in future a more prominent place for this metal.

To the abundant elements belongs also the semi-metal titanium, but the element is practically unknown in industry. Titanium oxide occurs in nature as rutile and with iron as ilmenite. Small quantities of titanium ores are used in making ferrotitanium and cuprotitanium which are employed in the manufacture of electrodes for arc lamps and also in the steel industry. Considering its relation to silicon and carbon this element deserves more attention. Some of its salts are used in dying leather and textiles, but undoubtedly the properties of this element can be utilized in other ways. It is safe to predict that the development of the chemistry of titanium and its compounds will bring forth many new and useful applications.

Among the other metals in the list of abundant elements are also manganese, barium, chromium, nickel, vanadium, strontium and zirconium—all of them comparatively little used in the arts and industries. On the other hand the commonly

known metals—copper, lead, zinc, silver, mercury, gold and platinum—are not in the list of abundant metals. To gain an insight into the present importance of these metals the following shows the estimated production in 1915 in the United States:

Titanium (rutile)	250	tons
Manganese (ore)	8,708	"
Barium (barytes)	108,547	"
Chromium (chromic-iron ore)	3,281	"
Nickel (metal)	822	"
Vanadium (metal)	470	"
Lithium (minerals)	200	"
Strontium (nitrate)	520	"
Zirconium and Thorium (ore)	22	"
Copper (metal)	694,005	"
Lead (metal)	507,026	"
Zinc (metal)	458,135	"
Silver (metal)	3,124	"
Mercury (metal)	789	"
Gold (metal)	204	"
Platinum (metal)	0.3	"

An examination of this table reveals the desirability of developing the metallurgy of the more abundant metals and increasing their production and consumption. The problem of the inventor is then to substitute the less abundant metals, as present extensively used, by the more abundant metals, at present little used. Thus the consumption of copper is extremely large and should and could be replaced in part by nickel. Lead might be replaced by zirconium and titanium. Manganese, chromium and vanadium might take the place of lead and zinc in electrical appliances. The logical conclusion from a study of the tables will lead to the somewhat dogmatical statement that the consumption of copper, lead, and zinc should be curtailed, while the production and consumption of titanium, manganese, chromium, vanadium, zirconium and especially nickel should be increased. Few have seen the latter metals in their elemental form, and to many even the name is unfamiliar. Considering, however, that 70 years ago aluminum was a laboratory curiosity, a pound of which was priced at about $400, there is hope that some day the now expensive although abundant metals will be within the reach of commercial and industrial exploitation.

The Chemistry of the Brain*

A Difficult but Fascinating Field of Chemical Research

By Clarence Jay West

"THE brain and nervous system control, either directly by nerve impulses or indirectly through the blood stream, the metabolism and activity of all the other tissues of the body. They are, therefore, the master tissue of the body." While the nervous tissue comprises a relatively small part of the entire body, its superior reactivity or irritability enables it to control or set the pace for the other tissues.

The chemistry and metabolism of the nervous tissue are from almost every point of view the most absorbing and interesting of the problems of physiological chemistry. Matthew in his text-book states that the whole of evolution is characterized by the steady development of the nervous system, and by the steady development of no other tissue. The power of adapting the organism to a changing environment has been solved by the development of a tissue of the body which should be most irritable, which should control the other tissues, and which, having memory, could profit by experience. It is by means of his nervous system, and in that respect alone, that man stands at the summit of the animal world.

In spite of the importance and fascination which this study should possess, we know comparatively little regarding the chemical composition of the brain and the properties of the substances which are characteristic of nervous tissue. Much of our present knowledge is due to Thudichum, who worked comparatively unknown and entirely unappreciated, owing to his unusually combative nature, for many years (about 1865 to 1875) in England. The results of his investigations were published in the form of reports during this period, and later were collected in the form of a book under the title "The Chemical Composition of the Brain of Man and Animals." Among the later investigators in this field we may mention Koch, Fränkel, Rosenheim, MacLean, Thierfelder and Levene.

Our methods for analyzing the proximate constituents of the brain are far from satisfactory at the present time because of the complexity of the material in question. The following figures represent in a rough way the composition of the gray and the white matter:

	Gray	White
Water	85.3	70.2
Protein	7.6	8.6
Lipoids	3.1	18.1
Water soluble	0.5	1.4

*Reprinted from *Chemical and Metallurgical Engineering*, July 28, 1920.

The composition of the solids of the human brain is given by Koch as follows, the figures being per cent of dry matter:

	Whole Brain (Child)	Whole Brain (Adult)	Corpus Callosum
Protein	46.6	37.1	27.1
Extractives	12.0	6.7	3.9
Ash	8.3	4.2	2.4
Phosphatide	24.2	27.3	31.0
Cerebrosides	6.9	13.6	18.0
Lipoid sulphur	0.1	0.3	0.5
Cholesterol	1.8	10.9	17.1

The protein material of the brain is of the same general composition and nature as that found in the other parts of the body. If there is anything characteristic about it, it is the presence of normal amino-caproic acid. This is a matter probably of not very great significance, and it is unlikely that this acid is found only in brain protein.

The characteristic property of nerve tissue which differentiates it from all other tissues of the body is the presence of a large amount of ether and alcohol soluble material, which has been called by the collective name lipoids. The scope of this term varies with various investigators, but in general it has been used to include cholesterol, the nitrogen-containing bodies and the nitrogen and phosphorus-containing bodies. It is probable that there also exists a sulphur-containing body in the brain, but whether it contains in addition only nitrogen or whether it contains both nitrogen and phosphorus has not been determined.

CLASSIFICATION OF KNOWN BRAIN SUBSTANCES

The following classification represents our present knowledge of the substances which have been definitely established. The literature of lipoids is very confusing, because names have been given to bodies which are mixtures of two or more of these, or which contain other impurities.

I. Cholesterol. Really this should not be classed as a lipoid, and is included only because it occurs in the alcoholic extract of nervous tissue.

II. Cerebrins. (Nitrogen-containing) *a*. Phrenosin. *b*. Cerasin.

III. Phosphatides. (Nitrogen and phosphorus-containing.)

1. Ratio of N:P = 1:1. *a*. Lecithin. *b*. Cephalin.
2. Ratio of N:P = 2:1. Sphingomyelin.

IV. Sulphur-containing compounds.

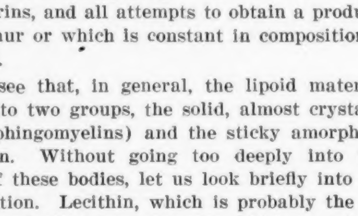
Let us first consider the lipoid materials by studying their methods of isolation. The fresh brain matter is carefully freed from the covering tissue, washed, ground in an ordinary meat grinder, and dried *in vacuo*. This drying is usually carried out at 95 to 100 deg. C. The dried material is then ground to a fine powder and thoroughly extracted with hot alcohol. This removes all of the lipoid material, although as the process of purification continues a large part of it becomes insoluble in alcohol. Upon cooling the alcoholic extract, a large amount of the cholesterol and a certain amount of the nitrogen and nitrogen- and phosphorus-containing bodies separate out.

The filtrate will contain the greater part of the lecithin and cephalin. This is evaporated to dryness or to a thick syrup in vacuum and poured into acetone. This procedure precipitates all of the lipoid material and is a means of separating this from the fats and cholesterol. Because of the solubility of the lipoids in one another, this lecithin mixture will contain a considerable amount of the cerebrins and some sphingomyelin. The latter are insoluble in ether, and, therefore, extraction with ether will remove the lecithin and cephalin. Cephalin is insoluble in alcohol, and by dissolving the lecithin-cephalin mixture in ether and pouring this solution into alcohol, we are able to effect a certain separation of lecithin and cephalin. The procedure is very tedious, but finally results in the preparation of a cephalin which is free from lecithin. The preparation of a pure lecithin involves a considerable amount of additional work.

The mixture of cerebrins and sphingomyelins may be separated by a complicated system of precipitation and fractionation, involving the use of acetic acid, petroleum ether, alcohol, and pyridine. The details of this method have been worked out by Levene and will not be given here.

The sulphur-containing body is found in the same fraction as the cerebrins, and all attempts to obtain a product which is rich in sulphur or which is constant in composition have been unsuccessful.

We thus see that, in general, the lipoid material may be separated into two groups, the solid, almost crystalline (cerebrins and sphingomyelins) and the sticky amorphous lecithin and cephalin. Without going too deeply into the organic chemistry of these bodies, let us look briefly into their chemical composition. Lecithin, which is probably the best known of all of these bodies, is a glyceride which contains one molecule of stearic acid, one molecule of an unsaturated acid, which probably belongs to the oleic acid series, while the third hydroxyl of the glycerol is esterified by means of phosphoric acid, which in turn carries a choline residue. That is, the lecithin molecule may be represented by the following formula:



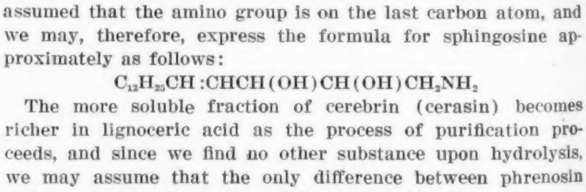
Our knowledge of the chemistry of lecithin was greatly increased by the application of the principle of reduction with hydrogen and palladium, because by this reaction one is able to obtain a crystalline body. Upon hydrolysis of this crystalline lecithin we obtain only stearic acid. This, therefore, does away with the possibility which many investigators have thought probable, that lecithin was a mixture of a stearic acid and a palmitic acid glyceride.

The chemistry of cephalin is much more complicated. Thudichum, who first isolated this body, observed that the carbon content was approximately 60 per cent. The products of hydrolysis were found to be glycerol, stearic acid, an unsaturated acid probably of the linoleic series, phosphoric acid and amino-ethyl alcohol, $NH_2CH_2CH_2OH$. If the composition is calculated from these components, it is found that the carbon should be 66 per cent. Thudichum noticed this discrepancy between the observed and calculated values for carbon, but made no attempt to account for it. Later investigators likewise obtained a cephalin with 60 per cent of carbon, but no attempt was made to explain this difference until Levene started his work. Levene and West spent a year in attempting to so purify cephalin that the carbon content would be raised to 66 per cent, but without success. The attempt to reduce cephalin with hydrogen was at first unsuccessful, but lately reduced cephalin has been prepared. Various derivatives, especially urethanes, were prepared, but these were unsatisfactory because of their amorphous nature and threw no light on the composition of the body in question. Very recently Levene has been able to show that it is probable that during the process of purification there is a certain decomposition of the cephalin molecule and that one fatty acid radical is split off. Either this is the explanation or there occur in the brain two cephalins, one of which contains two fatty acid residues, while the other contains only one.

The cerebrins are a much more satisfactory class of compounds as regards work in the laboratory. They crystallize readily from alcohol and other solvents. Here again we find that we are dealing with a mixture of two substances. By careful fractionation from a number of solvents one is able to obtain a more insoluble fraction, which is found to contain only cerebronic acid. Cerebronic acid is a hydroxy-acid which contains twenty-five carbon atoms, and which on oxidation yields lignoceric acid. Lignoceric acid is familiar to some of us because it has been isolated from the soil and from wood. The other components of this more insoluble fraction, which has been given the name phrenosin, are galactose and sphingosine. Galactose is of course a well-known sugar. Sphingosine has been shown to contain seventeen carbon atoms, two hydroxy groups and one amino group, together with an unsaturated bond. By oxidation of sphingosine it is shown that the unsaturated bond is between the thirteenth and fourteenth carbon atoms, since the product of oxidation was tridecylic acid. Upon reduction and subsequent oxidation pentadecylic acid was obtained. This indicates that the amino and hydroxyl groups are located on the last three carbon atoms. Various attempts have been made to prepare the unsubstituted amine from sphingosine in order to locate the relative positions of the hydroxyl and amino groups. These efforts have been unsuccessful thus far. It has generally been assumed that the amino group is on the last carbon atom, and we may, therefore, express the formula for sphingosine approximately as follows:

$$C_{12}H_{25}CH{:}CHCH(OH)CH(OH)CH_2NH_2$$

The more soluble fraction of cerebrin (cerasin) becomes richer in lignoceric acid as the process of purification proceeds, and since we find no other substance upon hydrolysis, we may assume that the only difference between phrenosin and cerasin is in the nature of the fatty acid. It is, of course, desirable that an absolutely pure cerasin containing 100 per cent of its acid as lignoceric acid should be isolated. We may write the general formula of these compounds as follows:



Upon hydrolysis of sphingomyelin we obtain the following products: Sphingosine, identical with that obtained from the

cerebrins, choline, phosphoric acid, and a mixture of fatty acids, one of which is lignoceric acid. The other acid appears to have the composition of a hydroxy-stearic acid, but this is not definitely established because of the difficulty in obtaining this acid in a pure state. It is still an open question as to whether there are two sphingomyelins, one containing cerebonic acid and the other hydroxy-stearic acid, or whether the molecule is a diphosphatide containing both of the fatty acids.

It is thus seen that the chemistry of the lipoids offers a large number of unsolved problems. The difficulties in the field are many, but even with all of these difficulties, the field is a fascinating one and still offers an opportunity for a real contribution to our knowledge of physiological chemistry.

EFFECT OF COLORED LIGHT UPON PLANT GROWTH*

NOTICING the pale appearance of the leaves of a plant kept in a room painted and decorated with various shades of blue, the writer assumed that the wall color may have had some effect upon the development of the chlorophyl (coloring matter) in the plant, since the production and continuance of chlorophyl is ordinarily dependent upon the action of sunlight (white light). This observation suggested an experiment to determine the effect of various other colors upon the growth of plant life. Accordingly a number of potted belladonna seedlings were selected because they were easily obtained of the same relative size and in vigorous condition. Potted plants were placed under each of a number of large porous paper cones of sufficient height and width to prevent interference with the growth of the plants. The interior surfaces of each cone were painted with relatively pure colors in distemper form, including white, red, orange, yellow, green, and a purple tone of solid blue. One set of the tests was maintained in the laboratory in a position to receive indirect sunlight, and another set was placed on the roof of the laboratory, in direct sunlight. Control specimens of the potted plants were also maintained without the cones.

Within three days it was noted that some of the leaves of the plants under the purple tone blue color had bleached out to a light yellow. One yellow leaf had broken off at the stem. There was marked evidence of what might be called plant fatigue. When the plants were returned to sunlight they were restored to their normal, vigorous condition, the yellow leaves rapidly becoming green again.

Under the green cones, some yellowing of the leaves was shown, but the plants were apparently in good physical condition. The red, yellow and orange colors apparently had no

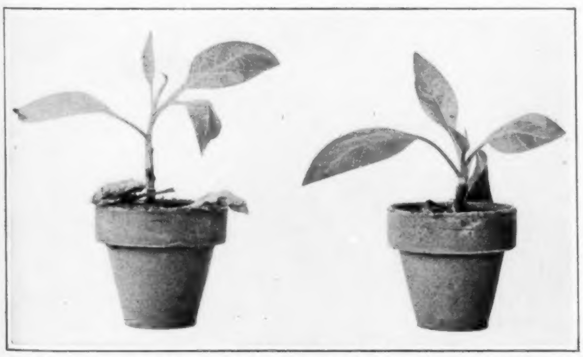


FIG. 1. BELLADONNA EXPOSED TO INFLUENCE OF (LEFT) BLUE PAINT, (RIGHT) ORANGE PAINT

marked effect either upon the pigmentation or growth of the specimens. The plants under the white cone were vigorous and of normal color. Some of those under the black cones had grown much more rapidly than the others and had fully maintained the original green color of the leaves. This latter result, in so far as the growth was concerned, was at first attributed to the fact that the earth might remain damper for a longer period in the pots under the dark cones; the greater resulting humidity causing a more continued growth. However, this test indicated that illumination is not always necessary for the continuance of plant life, and that sunlight is not always required to produce or at least maintain the green coloring matter.

Another series of tests was then made in three small chambers constructed of wood and provided with means for admitting air. The interior of the chambers was painted in red, yellow and purple blue respectively. The roof of each chamber, where the light was admitted, was covered with colored glass to correspond with the color of the walls. Belladonna plants in one test and tomato plants in another were placed in the chambers for one week. The results corresponded to those obtained under the paper cones, except that the etiolation was more rapid in the case of the purple blue. One plant showing yellow leaves was restored to normal condition by removing it from the box and placing it near a quartz tube mercury light sending forth strongly actinic rays.

FIG. 2. TOMATO PLANT EXPOSED TO INFLUENCE OF (LEFT) BLUE, (RIGHT) RED PAINT AND GLASS

While the experiments outlined above are but of a preliminary character and cannot be relied upon to indicate what might happen with other types of plants under similar conditions, or even the same plants under longer periods of exposure, they are nevertheless of some interest as indicating that the color of the interior sash of greenhouses might for some plant life preferably be of a dark shade instead of white. Possibly a glaze color on the glass, or the use of colored glass might also be found useful in certain instances. A further study of the subject by competent botanists might show that plants having active medicinal, alkaloidal, or aromatic principles could be stimulated to produce larger yields. It is possible, moreover, that plants yielding oil seeds might be so grown as to prevent the development of chlorophyl which causes the yellow-green color in drying oils. A water white oil might thereby be obtained.

The above tests also suggested to the writer that color environment might influence to some extent the shade or tone of pigments precipitated in vessels under colored light. Accordingly, triplicate samples of blue and of an organic red lake were precipitated in colored chambers roofed with colored glass, and left therein for a period of 10 hours before removing to observe the color. While the results obtained were not startling, a slight difference in the tone of some pigments precipitated under different colored lights was indicated.

The Psychology of the Dreamer

An Analysis of the Elements Involved in the Process of Dreaming

By Prof. Yves Delage

The eminent author of this article passed away on the 8th of October last. He was in charge of the Roscoff Marine Station in France and had an encyclopedic knowledge of shore fauna. He was intensely interested in problems of biology and particularly in psychobiology. The subject of dreams had always a great fascination for him and he had studied them for many years, but in the latter part of his life he devoted himself to a more intense research in this field. In fact he was at work on this very subject when death overtook him.

The following article is taken from advance pages of Professor Delage's book, which he furnished to the international scientific periodical Scientia (Bologna) two years ago and from whose pages the following translation has been made for the SCIENTIFIC AMERICAN MONTHLY.—EDITOR.

FOR the purpose of making a profound analysis of them it is necessary to consider dreams under three aspects which are entirely distinct and in each of which the psychological condition of the dreamer plays a different rôle. The first thing to be considered is the framework of the dream, consisting of the setting or inanimate objects perceived together with the actors concerned and the "supers" present, to use a theatrical term. Secondly, we must direct our attention to the movements of the actors, who include the dreamer himself. And thirdly, we must examine the thoughts which pass through the mind of the sleeper and his opinions and judgments with regard to the relationships of the events he perceives and to their interpretation, their causes, and their consequences.

1. Let us first inquire whence come the mental images which constitute the scene of action. These have their origin in what Hervey de St. Denis has called in a phrase as exact as it is picturesque, *a set of memory-negatives.* Within the depths of our unconscious mind there slumbers an infinite multitude of images, the memories of past impressions or even of simple concepts which have lingered there after having expended, at the moment of their formation, a more or less important part of their initial energy. Every thought, in fact, and every impression perceived possesses a certain amount of potential energy, which it receives from the emotion which is inseparable from every psychological perception or concept: the more it moves us the more energy it has to expend before falling into forgetfulness by reason of the progressive exhaustion of the interest which it excites in us. This degree of initial energy is never entirely expended at the time of the origin of the impression; there always remains a residue which must some day be expended in some manner and this residue may be very important in those frequent cases in which there has intervened at the moment of perception an accidental inhibition either by reason of some concurrent impression or else because of a voluntary repression for intellectual, aesthetic, or moral reasons. This residue constitutes an individual characteristic belonging to each impression which slumbers in the unconscious mind, which reveals itself by a revivifying energy, which renders it more or less apt to reappear again in the conscious mind. It may be remarked furthermore that these memory-negatives while concrete in origin are capable of being decomposed with extreme facility into their various elements, from the principal features to the faintest details; each of these elements possesses its own individual degree of revivifying energy and is capable of being individually revived by the association of ideas in consciousness and of reassociating itself with new images which may differ so greatly from the memory-negatives from which they are derived as to appear to be products of the creative imagination.

These images, or rather these elements of images constitute the subject matter of oneirical representations of which they are in some sort the chief factor; but it rarely, if ever, happens that the revivifying energy is sufficient in itself to open the door of the conscious mind to an image; it is necessary that it should be aided by some outside force. The latter may possibly consist of one of the sensory or kinesthetic impressions which are vaguely perceived by the sleeper, but in our opinion the part played by these has been greatly exaggerated—in our view it is mainly the association of ideas which enables thoughts to enter the conscious mind. It is this association of ideas in all its forms which constitutes a stepping stone for the images which slumber in the unconscious mind and enables those which exhibit some degree of resemblance to one of the images actually present in the conscious mind to enter the latter accordingly. Partly impelled by their own revivifying energy and partly drawn forth by the association of ideas, these images enter the conscious mind one after the other, taking the place of those which have helped to draw them forth and which then make way for them. We may sum the matter up by saying that the aptitude for passing from the unconscious into the conscious mind is measured by the product of two factors, namely, the energy of revivification and the association of ideas; the comparative strength of these two factors matters but little, the only thing to be considered being the magnitude of their product. It is evident that each of these factors is absolutely independent of the will power of the dreamer and lies entirely outside the scope of his own initiative.

Thus there marches through the brain of the sleeper a series of images in whose succession there is nothing arbitrary, since they are connected by associative ties by means of which each of them draws forth the one which follows. But the dreamer does not perceive these connecting bonds; consequently the images appear to him to be entirely independent of each other. As respects the images which succeed each other in his conscious mind he is in the position of a spectator looking through the eye-piece of a kaleidescope which is whirled by another's hand. Although the images come from his own mind and are really part of himself he takes them to be facts in the external world entirely independent of himself.

2. Let us pass now to the part played by the actors. For the dreamer this, like the presence of the actor himself, is a fact belonging to the external world, while the part he himself plays appears, however, to be a manifestation of his own will power. There can be no doubt concerning this last point. . . . But this will power is usually, if not absolutely always, a characteristic of the dream; it is a will power which is set in operation directly by emotional factors: the dreamer is incapable of willing anything which does not conform to the instincts, the desires and the fears which govern him at the moment and is incapable, save in rare exceptions, of being influenced by those more remote and important reasons which enable him when waking to combat the impulses of instinct.

As for the actions of persons other than himself, these may have their origin partly in the memory-negatives: these are not merely lifeless photographs, they are the films of moving picture, rather. But this is far from saying that the actor always employs the same motions and gestures as in the real scene which forms the origin of the memory-negative: we

have here, in fact, one of the lowest examples of that dissociation of the elements of the dream which we referred to above and which here permits the dreamer to separate the performer from his performance.

One of the principal factors which determine the performance of the actors in the scene of the dream is the *emotional tone* which characterizes the actual condition of the dreamer during his dream. This emotional tone may vary from the *euphoria* which is the source of hilarious dreams to the anguish which is the mother of nightmare, passing through an infinite series of intermediate states—desire, fear, hate, doubt, disquietude, envy, jealousy, etc.—and the infinite variety of their combinations. The reaction of these emotional states upon the performance of the actors and also upon that of the dreamer himself, may be revealed in spite of its extraordinary complexity, by a remarkably simple formula: the dreamer makes the actors perform those acts which are capable of being produced and justified in himself by the kind of emotion to which he is subject at the moment.

As for these emotional states they appear to have their origin either in the kinesthetic condition of the dreamer, *i.e.*, in those obscure impressions which have their rise in the functioning of his organs whether this be more or less normal or abnormal, or else in the emotional residue of the impressions received in recent happenings, or, finally, in memories of former impressions of more or less recent date.

In spite of appearances the emotional tone of the dreamer to which we here ascribe a principal rôle is not a factor which is independent of those previously mentioned; it is only one form of the association of ideas, the definition of which must be enlarged to include this new series of phenomena. Everyone is familiar with the fact that even in meditation or reverie an emotional state of any particular sort opens the door of the conscious mind to all those memories which are related to the state in question. How then could it be otherwise in dreams? And by reason of the dissociation between the actor and the part he plays, the same personage who appears as Santa Claus in the dream of a quiet and healthy child, bringing the usual gifts, may appear to the child who is troubled with worms or who has been frightened by the tales of his nurse as an ogre ready to devour him and causing him to scream in the terrors of a nightmare.

The above is a crude and commonplace instance but it must be understood that it is possible for the most delicate shades of the mental disposition of the dreamer to reveal themselves in the slightest details of the attitudes, the gestures, and the actions of the personages beheld in the dream.

We have separated the scenes and the actors from the actions of the latter for the sake of clearness in finding the relation between each of these and its essential cause; but it would be a grave error to attempt to build a partition between these two classes of phenomena. Indeed, the mere energy of revivification and the association of ideas may bring into the conscious mind persons in action bringing with them the rôle they are to play; and furthermore the emotional disposition of the dreamer may contribute, by way of a special sort of association of ideas, to the entrance upon the scene not only of active or passive personages, but also of inanimate objects to furnish a background. We may say, therefore, that these three independent factors, the energy of revivification, the association of ideas, and the emotional condition of the dreamer help to determine not only the personages of the dream, but also their actions with infinitely varied details, which cannot be precisely determined, and of which it is only possible to say, in general, that one or the other will predominate according to circumstances.

To illustrate these remarks and to render them entirely clear to persons unfamiliar with the subject, it would be advisable to give concrete examples in the form of narrations of dreams. The limits of the present article forbid this, but all those who are interested in the question will easily find numerous examples either in their own personal experience or in the literature specially devoted to this subject.

The dreamer makes use of the images which present themselves successively in his conscious mind to construct a little narrative which he tells to himself and which these images serve to illustrate; he may be said, in fact, to resemble those so-called "poets" who improvise verses on the platform, to fit rhymes suggested by members of the audience.

The condition of the dreamer is very similar, therefore, to that of a waking person who abandons himself to reverie and composes a little story with the assistance of images which pass through his mind. But there is an important difference between these two cases: the man who is buried in meditation knows quite well that all these mental images correspond merely to concepts and not to either past or present sensory perceptions; just the opposite is true of the dreamer in whose mind the majority of these images take on the character of a hallucination. This hallucinatory nature is characteristic of the dream, and its origin is not less so.

In the waking state our sensory perceptions are distinguished from our mental concepts by the strength and clearness of the images they present in contrast to the faintness of those images which are of internal origin, but this entirely relative difference is worthless except for purposes of comparison and in the dream the absence of any sensory perception tends to intensify the mental images of internal origin, just as a slight murmur is emphasized in the midst of surrounding silence or a faint light in profound obscurity: in other words, these feeble impressions assume the importance under such conditions of strong impressions. The hallucinatory images of the dream may be actually no more vivid than the concepts of a reverie, but they appear to be so because there is nothing stronger with which to compare them.

We have just defined the materials of the dream and we may sum up the preceding remarks by saying that the dreamer constructs a little romance which lives by means of the hallucinatory visions which pass through his conscious mind and which he is obliged to accept as chance presents them, but between which he establishes an artificial and logical connection in order to reduce their incoherence to the minimum.

3. We now come to the question of the exercise of the psychological faculties during the dream and of that of the judgment in particular. The main fact which everyone recognizes is the diminution of the critical sense. What does this indicate?

The reason that the critical sense is deficient in a dream is because its exercise requires the simultaneous consideration and comparison of the manifold possibilities which present themselves of the consequences whether immediate or remote, direct or lateral, and the giving to each of its exact degree of importance. In the waking life the intelligence is more or less complete according to the degree in which the eyes of the mind are able to penetrate not only the distance which lies immediately in front of them, but also to cast their gaze in all other directions where objects which may guide the judgment are to be perceived. In the dream, on the contrary, there is a concentration of the mind which puts blindness upon the intelligence so to speak. The latter has a clear vision of the immediate matter with which it is occupied, but sees nothing else upon one side or the other. If it is in these lateral directions therefore that reasons for modifying the judgment are to be found, such reasons will pass unperceived and the judgment will be falsified.

The matter may be stated in another manner which exhibits the phenomenon under a new aspect and enables us to penetrate further into its more intimate depths. In the dreamer the faculty of attention is deprived of that initiative which enables it in a waking person to grasp all the points required to construct a complete judgment. The faculty of attention in the dream may, indeed, be at times exceedingly keen, but it is the absolute slave of that which attracts it and in particular of the ideas which are present in the conscious mind to the

exclusion of those which though quite closely connected and necessary for the formation of a complete judgment require for their penetration a certain degree of research, however small. In the same way the waking person is obliged to exercise his faculty of judgment only upon those elements which are actually present in his conscious mind, but on the other hand his attention is not, as in the dream, disinterested and deprived of initiative. He possesses a knowledge of the remote object of his mental operations and this is sufficient to evoke a crowd of associations of ideas, among which his waking critical sense knows how to choose those which circumstances demand. All his means of judgment are at his free and entire disposal, provided that he is neither inattentive nor distracted and that his power of association is normally developed. Just here we may remark that the person who is *distrait* or who suffers from amnesia, or who is unskilled in attention or reflection, or who does not know how to make research in the depths of his mind, will form judgments which are incomplete, false, or bizarre, and which will be, therefore, not dissimilar to those of the dreamer. The difference may be reduced, in fine, to the distinction which exists between the impulsive will power and the deliberate will power. . . .

To make perfectly clear this psychological condition, which to our mind constitutes the essential characteristic of the dream, let us apply the term of psychological riches or property to the total knowledge of all sorts possessed by an individual, from the loftiest intellectual and moral principles down to the most common-place data of common sense and including all those infinitely various ideas and acquisitions of facts which constitute his psychological past. In the waking state the thinker has his entire psychological property at his free disposal; he can call upon anything which finds a place in his memory, from the most ordinary ideas of simple good sense to those acquisitions which have been most laboriously acquired, and upon everything throughout his entire life which has left the memory of a perception or of a concept. All these things are not indeed present in his consciousness at one and the same time, but he knows that he possesses them and he knows where to seek for what he requires in order to exercise the actual process of reasoning and judgment. According to whether he is working up a problem in geometry or in experimental science, or upon a question in history, in politics, or sociology, he causes to pass before the eyes of his mind the series of theorems, principles, and experimental ideas of physics, chemistry or biology, or upon the other hand the historical, economic, and other data which bear upon the question in hand and which form a part of his metal luggage; if a fact is concerned he evokes, before his mind's eye, the times, the places, the persons, or the things which may enable him to recall it; and when he has found an answer he compares it with previous acquisitions to see whether it contradicts any of these.

In the dream the situation is entirely different. The dreamer who is engaged in the process of thinking and reasoning has no other materials at his disposal than those which chance causes to rise in his conscious mind, at the moment making the association of ideas its instrument. His psychological property is indeed the same in amount as when he is awake. . . . But he has at his disposal only those of its treasures which are present in his consciousness at the time being. He is absolutely ignorant that his psychological storehouse contains an enormous mass of things—of memories, of ideas of common sense, of memories, of scientific principles, of moral ideas—upon which he might call, but which can give him no aid for the very good reason that he does not suspect their existence. If the association of ideas, or some kinesthetic impression introduces a new element into his consciousness he makes use of it, and on the other hand if some other element escapes from his consciousness it immediately ceases to exist so far as he is concerned.

The use he makes of the materials constituted by the images which people his dream depends upon those principles of judgment which chance places in his conscious mind at the moment. Hence making use of these elements which are never indeed sophisticated or "doctored" but which are yet always incomplete, he forms his judgment in as assured a manner as if all his funds of information were at his disposal. In consequence of this fact the intellectual or moral quality of his judgments depends exclusively upon chance: it may be excellent at any given moment but may give way the next instant to conclusions of the utmost absurdity or the most monstrous moral character, merely because there is lacking in his consciousness for a time some given idea of morality or of logic, or such and such data of contingent or accidental facts.

Let us illustrate these statements by a few examples:

In the dream of the two clocks which is given in full in the appendix at the end of this article, the reasoning is entirely correct and even rather ingenious, whenever the data comprised are sufficiently complete. But apart from this it will be observed that I estimate the arc extending from St. Germain des Près to the Montparnasse Railroad Station as being several degrees in extent, because at that moment I ascribe a length of only a few hectameters to the diameter of the earth, being for the moment deprived of all information as to its real length—a knowledge, however, which I should have instantly recalled had I been awake; in the same way I attribute to the large hand of the clock the property of making a single revolution of the dial in twelve hours, because I know that that is the ordinary rate of motion of one of the hands, but I have forgotten, for the time being, that it is the short hand and not the long hand which does this. So much for the logic of the matter.

Let us now pass on to a question of facts. In my dream of the poisoned dog also related in the appendix, I was much concerned over the fate of a yellow basset dog with short hair, because his pleading eye made me mistake him for my own little dog Niña forgetting that since she had long black hair she could not be the same animal. All of the facts involved in the false recognition exhibited in dreams which has been such a subject of dispute can be explained in an analogous manner. When in the mind of the sleeping Egger ("*Rev. Philos*," 1898) there rises the image of a blond young man having an air of timidity and, at the same time, brought to the surface by another association, the idea of Gambetta arises, then for the dreamer this young man at once becomes Gambetta. And no protest with respect to the improbability of the correctness of such a recognition will be registered by the mind of Egger, since for the time being all the information which would prove to him the falsity of the recognition is absent from his mind.

Let us now proceed to consider moral ideas. In the dream of the Garibaldian if M.K. permitted himself to behave so execrably to the execrated Napoleon III., it was because there was absent from his consciousness, for the moment, the sentiment that such an act was doubly odious, both in its moral nature and because of the persons involved.

Let us end these remarks by a fact taken from the domain of simple common sense. If Eugene Bernard Leroy (*Quelques Rêves Symboliques, i.e.,* Certain Symbolic Dreams, "*Journal de Psychologie, Norm. Pathol.,*" page 358, July-August, 1908) in his dream of the symbolic bell tower, mistook a church tower for a young girl and found no difficulty in seeing the tower take its seat as a guest at a banquet, it is merely because the common sense idea that a clock tower cannot be a young girl and seat itself at table was for the time absent from his mind.

But we have now said enough to be able to formulate the psychological definition of the dreamer in a few phrases which will form the conclusion of this article:

The dreamer is a sufferer from partial not systematic amnesia; the field of his memory is at once restricted in extent and incessantly variable in form, in contours, and in localization. He utilizes correctly the materials which lie within his reach, and all the errors of which he is guilty, whether in the realm of facts, of common sense, of logic, or of morality

result not from any vitiation of the functioning of his brain, but are merely due to the circumstance that there are for the moment absent from his consciousness all of the ideas and information which would enable him to avoid such mistakes.

In contrast to certain sufferers from actual amnesia he is quite unconscious of his amnesia and behaves at any given time as if there were nothing in the universe outside the idea actually present in his consciousness whether with respect to the elements of morality, of logic, or of simple common sense or whether with respect to any sort of general contingent or accidental ideas, and in consequence he is deprived of all capacity for exploring the realm of his memory with regard to all those points which are at the time outside the domain of his consciousness.

The state of war in which we are existing at present suggests a comparison which may aid us in comprehending these incessant variations of the field of consciousness during the course of a dream: The siren has sounded the alarm, the airplanes of the enemy have been sighted, the searchlights are turned on, and at once there is seen in the sky a luminous spot moving about in the most capricious fashion, illuminating now this and now that portion of the heavens, while the background remains dark. This luminous spot, forever in motion, is the mental psychical consciousness of the dreamer, while the obscure background represents all the rest of his psychological property, lying for the time outside the field of his consciousness. His intellectual universe is reduced to this small illuminated field, always the same in extent and yet always in motion.

APPENDIX

Dream of the Two Clocks.—I find myself in the Rue de Rennes upon a balcony of a house situated rather near the Rue du Vieux-Colombier; I look toward the right and perceive the clock of St. Germain des Prês, which is opposite to me (contrary to the actual fact). I see that it is a quarter to 11, and I then turn my head to the left, and by chance, without my having tried to do so, my eyes fall upon the dial of the clock of the Montparnasse Railroad Station. The hands stand at 10 minutes to 11, and I begin to reason about it thus: Why do these two clocks show different times? One of them, I say to myself, is doubtless badly regulated; then suddenly an admirable idea occurs to me: "How stupid I am," I say to myself; "it is because of the difference in the meridians." But does this difference in the time really correspond to the difference of the meridians? In order to find the answer to this, instead of estimating the distance between the two clocks, I draw an imaginary line from each of them to the center of the earth, and since in my dream the earth appears to be much smaller than it is without causing me to feel any surprise, I find that these two radii form an appreciable angle, and this angle is one of exactly 30°, like that made by the long hands of the two dials. At first this satisfies me, but then an objection rises in my mind. The hand of the clock goes twice round the dial while the earth makes one revolution, hence the angle ought to be twice as large on the dial of the clock as upon the earth; if it is merely equal then there must be, just as I thought at first, an error in the regulation of the two clocks.

It will be observed that I reasoned very precisely and correctly in my dream, while at the same time I was unconsciously guilty of a triple absurdity: first in estimating at 30° the difference in longitude between the railroad station and the church; second in comparing the motion of the earth not with that of the short hand, which really does go twice as fast, but with that of the large hand, which moves 24 times as fast; third in not having perceived that in any case and whatever the cause, the station clock should have been slower and not faster than the church clock, since in my dream I saw the former precisely west of the latter, this latter idea having its origin doubtless in the fact that whenever I take the train at the said station it is always in order to travel west of Paris.

Dream of the Poisoned Dog.—Some preliminary data are necessary for the understanding of this dream. I possess 4 dogs, 3 of them being shepherd dogs with short hair, while the fourth is a fox terrier having a white coat spotted with black. A few years ago I had a remarkably intelligent and devoted black poodle named Niña. I had been obliged to sacrifice her because she had become both deaf and blind. I have never owned a short-haired yellow dog, and none of the dogs with which I am well acquainted has these features, but a few days ago the person with whom I was walking pointed out to me a dog in the street having much such an appearance. I should add that one of my shepherd dogs being troubled with a *tenia* it was planned to give him a dose of medicine.

In my dream this dose had just been given to the dog and the animal which had taken it exhibited all the signs of suffering from poison; he dragged himself painfully along, fell gasping for breath to the ground, and seemed a prey to sharp pain. He gazed at me with his gentle, pleading eyes as if to ask me to relieve him. I was profoundly affected. I picked him up and comforted him with words and caresses, but I felt myself powerless to help him and my eyes were filled with tears. What made my sorrow so lively in the dream was that this animal was not one of the shepherd dogs, but my dear little Niña. And yet the aforesaid Niña was in reality a black poodle, though the dog in my dream had an entirely different aspect, being much larger, with short yellow hair, and with a long, heavy, low swung body—and yet this difference of appearance did not disturb me, nor prevent me from "recognizing" my little Niña, who was doubtless present in my mind. And then I awoke!

THE INCUBATION OF EGGS IN ANCIENT EGYPT

It is usually thought that the artificial incubation of eggs is an entirely modern process. However, that idea is quite a mistake, since an irrefutable document has been recently dug up from the archives of the French Academy of Sciences, proving that artificial incubation was practiced in Egypt, in 1677, and was doubtless at that time already very ancient.

It was done by means of huge furnaces. The heating of these to the proper temperature started about the middle of January and continued until the middle of February, by which time they were so hot that a hand touching the wall could not bear the heat. The heat was furnished by camel's dung, 100 lbs. of which were placed in the furnace each morning and each night. When the proper degree of heat was reached, the placing of the eggs in this curious incubator began and was continued until the end of May. They were first placed upon a layer of straw at the bottom of the furnace which was built flat to the ground. Only two layers of eggs were placed in the furnace and the size of the latter is indicated by the fact that it commonly contained from 7,000 to 8,000 eggs. The fires were built in the upper part of the furnace in long, shallow channels. Since the furnace men owned no thermometers they regulated the heat by the unusual and ingenious method of placing the eggs against the eyelids of girls; so long as the heat of the egg was not too great to be borne by the tender skin of the eyelids there was no danger that it would be baked instead of being hatched.

The eggs were allowed to remain in the bottom of the furnace for two weeks and were then changed to the top part of the furnace placed immediately above the bottom. No more fire was made in the furnaces but the eggs were turned four times per day. The chicks began to appear on the 21st or 22nd day of incubation. They received no food the first day but were fed with wheat and other grain on the second. The owner of the furnace charged a fee of one-third of all the eggs entrusted to him, but he was obliged to give back two-thirds of the number in live chicks, replacing those broken or stolen from his own stock.

Courtesy, Amer. Mus. of Nat'l Hist.

REALISTIC REPRODUCTION, IN THE AMERICAN MUSEUM OF NATURAL HISTORY, OF A PEREGRINE'S EYRIE IN THE PALISADES OF THE HUDSON, NEAR EDGEWOOD, NEW JERSEY

Feathered Hunters Who Work for Man

The Ancient Sport of Falconry, a Pastime Well Suited for Modern America

By Thomas C. Turner

THAT the art of hunting with the hawk is one of the most ancient pastimes is attested by records of its existence in China as far back as 400 B. C. America in the early days shared with the rest of the world the passion and the sport of falconry. Some years before the Pilgrim Fathers landed, in fact as far back as 1585, Thomas Harriot wrote of it. In 1610 William Strackey enumerated among the birds of Virginia five different kinds of hawks. Izaak Walton in this "Compleat Angler," 1635, gives the falcon of Virginia a high place in his category of the sports of the English gentry. Frank Forrester, in "Field Sport," 1849, wonders why falconry had not survived on the prairies, which are as he says "for perfection, par excellence of the world."

English literature abounds with references to falconry; Chaucer's "Canterbury Tales," Spenser's "Faery Queen," and in many of the plays of Shakespeare are to be found simile and moral, drawn from the incidents, or clothed in the language of the falconer. It is to be expected that Sir Walter Scott should refer to the falcon because the sport lingered in Scotland much later than in England. Tennyson gives a most vivid description of falconry in the "Idylls of the King."

The extent of its practice may be judged by its literature the world over. Even in the most remote countries works of falconry are to be found. They are printed in Greek, Latin, Arabic, Egyptian, Persian, Hindu, Spanish, Italian, Russian, German and Japanese, the latter often profusely illustrated, for art too has claimed its share in depicting the falcon and falconry; thirteenth and fourteenth century manuscripts, both French and English, bear evidence of this.

Landseer over and over again chose the incidents for his pictures, and curiously enough the famous Bayeux tapestry depicts the arrival of Harold at William's Court with hawk on wrist. New York's Central Park has contributed its quota to art in falconry by its beautiful statue erected just to the side of The Mall. Hawks were a subject of courtesies in exchange between the monarchs of Europe, in fact it was for a period the sport of kings and princes, others not being permitted to indulge in it. All the Tudors were devoted followers of the sport, Henry VIII nearly lost his life in following it; Queen Elizabeth, that keen sportswoman of royalty, almost daily indulged in falconry. Whether it were the invention of firearms or the passing of some blue law of the Cromwellian period, hawking in England was discontinued after centuries of such popularity, and lay dormant for years. There is one point however which would always have a tendency to make its temporary cessation become permanent, and that is the fact that the sport can only be carried on by a continual breaking in of wild hawks. The hawk is not bred in captivity, and therefore could not lie by and be taken up in years to come ready to hand, as might be the case in some breeds of dogs, for instance. Hawks have to be obtainable in a state of nature. That at first might present little difficulty, yet as the skill of the falconer died out, as it would in time for want of practice, the effect would probably be permanent.

Had not the craft lingered on among a few of the inhabitants of the remote districts of the Highlands of Scotland, and a few Hollanders, we might have completely lost the art and mystery of teaching. The sport had almost completely died

out by the year 1700, and it is doubtful if there was anyone professing the art except the hereditary High Falconer to the Crown. Fortunately, however, under the leadership of that famous sportsman, Colonel Thornton of Thornton Royal in Yorkshire, the pastime was revived, for he gathered together the remnants of the craft both in Scotland and England, about a century and a quarter ago, and a marked revival of falconry followed, the Falconers' Club bringing back the sport to almost its original status. Since that time falconry has flourished in varying degrees, and few more delightful books exist than Colonel Thornton's "Sporting Tour in the Highlands" with records of his hawking there in 1804. Although falconers are by no means numerous, falconry is again a recognized profession. The main point in the craft is to render the birds obedient; nature has made them skilful and deadly. There are two schools, those of Holland and those of Scotland, and they take different courses in preparing their hawks for the quarry. Also there are two classes of hawks, the long-winged and dark-eyed, and the short-winged and yellow-eyed. To the first mentioned class belong the Gerfalcon, Peregrine, Lanner, Saker, Barbary falcon, Indian Sharkim, the Hobby and the Merlin; in the latter class are the Goshawk and Sparrow hawk. The methods of hunting differ between these two classes of birds; the long-winged birds take their prey by rising above it and "stooping," as it is termed, from a height, and striking their victims to the ground. Birds of the short-winged class hunt at a lower range, pursuing their quarry in a straight line and overtaking it by superior speed. The short-winged varieties are mostly flown to partridge and quail, the goshawk being especially good on wild fowl, rabbits and hares.

WILD HAWK AND THE DECOY PIGEON IN THE TRAPPER'S NET

In Holland the hawk is caught when on passage; the birds thus trapped have, as they are taken from the trap, a small sack or sock as it is called, fastened over their legs and wings so that the work of "manning" (getting them accustomed to human beings) may be more readily accomplished; for they must be broken in from the start. They have not to be taught the art of killing; that they well know; but they must be taught to obey and to stand proper handling.

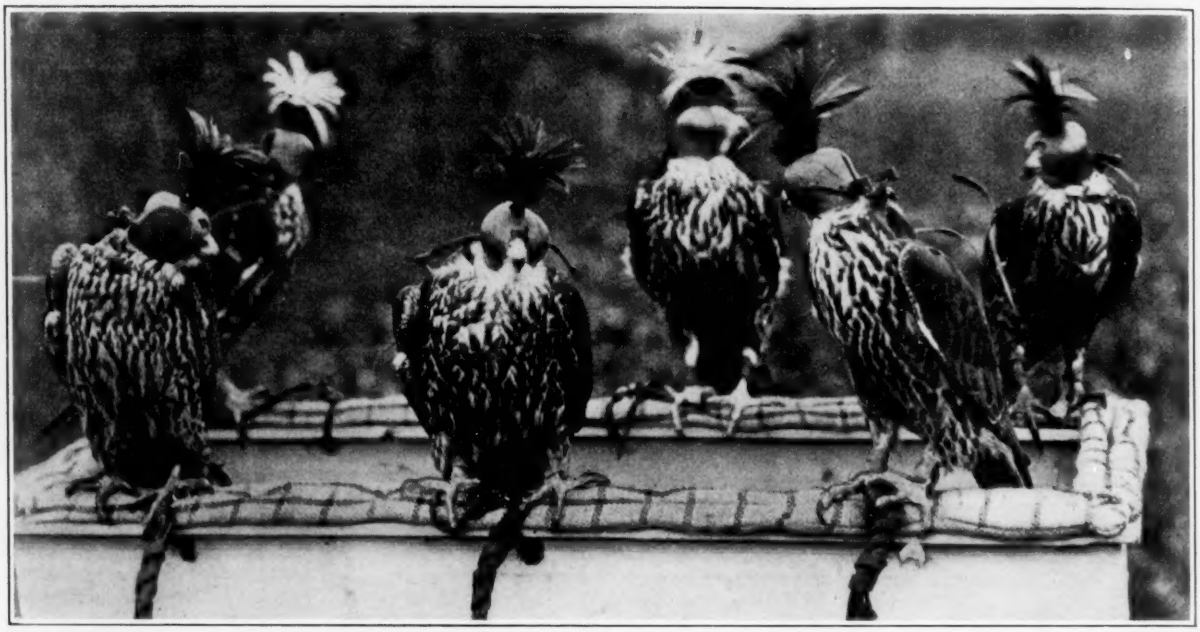
Passage hawks are quickly "jessed" and hooded, jesses being the term used for the soft leather straps which encircle the leg of the hawk and to which is attached the leash, to keep him captive, which is of course necessary to prevent him from flying off to hunt on his own account. He is fed daily through the hood for a time, and as he gradually becomes accustomed to his handler the hood is removed. These hawks are fed upon the gloved hand of the trainer, falconers using a special leather gauntlet for this, and all practices connected with the handling of the hawks are conducted with the gloved hand. It is curious that eastern falconers are generally depicted carrying their hawks on the right hand, whereas European falconers almost always carry on the left, leaving the right free for adjusting jesses, removing hoods and other necessary acts. The method of catching the passage bird, as practised in Holland is quite an interesting and exclusive art. Like many other forms of trapping it has been handed down from generation to generation, as in the famous Mollen family.

The trapper builds a cover much as we do in duck shooting, but this cover is mainly built of rough turf on top, with an excavation deep enough for the trapper to get in and, through a narrow opening, watch his decoy and trap which is at a distance. The wild hawk is by nature very wary; it is therefore necessary for the trapper to enter his blind at an hour that will avoid observation. In addition to the bait which is usually in the form of a semi-captive pigeon, the trapper depends upon his small assistant, a captive shrike. This little bird is located part way between the blind and the bait, and is the means of a quick signal to the trapper of the approach of any hawk, so that the trapper may be alert when the hawk stoops to his prey. The trapper with lines in hand soon springs the net and the hawk is captive.

The Scotch falconer pursues what is often a more dangerous course, that of taking his birds from the *eyrie* or nest, in the cliffs of the coast of Scotland; these nestlings or "eyess" as they are called, begin their new life in a state of "hack" or partial liberty, and their education also starts at once. The youngsters are daily accustomed to the falconer's voice, and

TRAPPER WATCHING FOR THE APPROACH OF A HAWK

CAPTIVE SHRIKE ON DUTY



HOODED HAWKS "MANNED" AND READY FOR SHIPMENT FROM HOLLAND TO THE OLD HAWKING CLUB AT LYNDHURST, ENGLAND. NOTE THAT THE RIM OF THE CAGE IS PADDED TO PREVENT INJURY TO THE FEET

are daily "called off" as it is termed, that is, gradually trained to come farther and farther for their food. It is not long before they must be taught to sit quietly on the wrist of the falconer. In their early days they are quite playful and as mischievous as kittens, but they gradually sober down to the stage where they must be hooded, with their "rufter hood," that is, the plain leather hood used in training. Hooding is a task which requires great patience on the part of the trainer, or the youngster may be spoiled for hunting. The young hawk's movements are now restricted to the length of his leash, for he soon grows out of his babyhood, and would readilly follow his natural course. As his training advances he is accustomed to his *bewits* and bells, which are made fast to his leg, bells being used on all trained hawks, when they are flown, to distinguish them from the wild hawk.

With the schooling completed the hawk is ready for work. The question then arises as to the game available for your bird and the nature of the country in which you wish to hunt. Hawks are of vastly different proportions and strength, and the killing range of each is consequently limited to certain lines. The four principal hawks used are the peregrine, the merlin, the goshawk and sparrow hawk. The gerfalcon of Norway is now rarely used, and the little hobby, perhaps the most graceful of all the hawk family, is little seen. Of these varieties the peregrine is the most popular, and the most useful. This hawk is also known in America as the duck hawk, but those used in England are mostly obtained from the cliffs of Scotland or from Holland. The merlin comes from the English moors, the goshawk from France. The sparrow hawk is the only one quite common in England. The lanner, which figures in Cassin's illustrations of American birds, was at one time quite frequently used by England falconers.

The male hawk, or what is generally termed the *tiercel*, is not as much used for hunting as the *falcon* or female hawk. The latter is invariably a stronger and better bird, to quote from Kipling: "The female of the species is more deadly than the male," and with hawks it is a veritable truth. While we often hear the phrase "keen as a hawk," it would be more fitting were it "keen as a falcon."

A well-trained hawk, will, according to its schooling, kill freely, grouse, duck, snipe, widgeon, rook and other such birds. The goshawk is flown to pheasants and partridge. Being of larger and stronger proportions it can be used in more enclosed country. The artist, F. Barlow, in his picture, "English Falconers of the XVII Century," shows the goshawk used on pheasant. Some years ago the Duke of Leeds had one that killed over a hundred partridge in one season, an instance of what a well-trained hawk will do.

When a covey of partridge is put up the goshawk selects one bird, and will pass through all the others to strike that bird. So keen and courageous a sportsman is she that she will sit unhooded on the glove, waiting for her game.

Her chase for the rabbit is most interesting; she will swoop along until she can strike, and she usually does so with one foot on the rabbit's head, the other as far back of the ears as he can stretch. It is seldom that the little animal escapes to his burrow.

The peregrine is perhaps the most courageous of them all. These falcons know no fear. They are most eager to kill; their strike is swift and powerful, and they go into the battle confident of conquest; yet they are as docile as any to the bidding of their handler. Her mode of work depends upon the quarry she is to fly. If it be grouse she is cast off where grouse are known to be. The falcon rises and circles round "waiting on" the falconer and his party, often for quite a long time, until the dogs spring the game; then when the grouse take the air, the hawk marks his bird, coming down with force enough to break the grouse's back. Sometimes of course the bird is able to dodge, but unless cover is close at hand, there is little chance for escape, for the falcon quickly recovers and rises for her second swoop.

In the southern and eastern parts of England the falcon is often flown for rook. This usually results in a real game fight, for the rook is strong and swift and will go far up into the blue with the falcon in hot chase. When flying rook the falcon is not cast off to "wait on"; there is no need for that. She is kept hooded until the rooks are in sight and comparatively near; then she is unhooded. As soon as she singles out her bird, and rises above him, he starts his downward course. There is no chance in this flight for a drop upon him; he is too near her match in speed, so she glides with tall closely compressed and makes her clutch. Usually the fatal grip results in a headlong fall, the rook fluttering in the tiger talons of the hawk.

The other long-winged hawk, the merlin, is quite different. She is small, slim, beautifully marked, and graceful. She has

ever been the lady's hawk. They were in olden times such constant companions that they were even taken to church. The merlin is a gentler bird than the others. She will sit unhooded, and after killing will return to the wrist. But though of gentle mood she is fierce in the chase, and for her size, as bold as any falcon. She kills in a manner peculiar to her; she strangles her quarry. Naturally she is not flown to large game, rarely anything as large as a pigeon, larks and other small birds being her specialty.

There are in the American Museum of Natural History some very excellent specimens of both American and European hawks. Almost all of the hawk family are very handsome birds, from the beautiful white gerfalcon down to the tiny speckled sparrow hawk; nearly all are of a dark brownish hue, particularly as to wings and back, but the breast and legs of many are most beautifully speckled from medium to coarse, or finely penciled as in the case of the goshawk. Light-colored hawks are rare, the gerfalcon and the white goshawk of New South Wales being the only ones among the scores of hawks in various parts of the world.

Harting, in writing of the "Birds of Shakespeare," says that "The rank of the owner was indicated in ancient times by the bird he carried. To a king belonged the gerfalcon; to a prince the male peregrine; to an earl the peregrine; to the lady the merlin; a young squire the hobby; a yeoman the goshawk; a priest the sparrow hawk; and to a servant the kestrel." The kestrel is the most easily tamed. It was in training these that many gained their early experience for future falconry with the larger birds. It is often believed that the hawk is an undesirable bird, and unworthy of protection. On the contrary he is of use in our agricultural interests, for he will rid a district of mice, and not, as his

Courtesy, Metropolitan Mus. of Art
PEREGRINE MOUNTED ON THE MAIL GAUNTLET OF A ROYAL FALCONER

false accusers state, of chickens. The red-shouldered hawk of this country, known as the "chicken hawk," rarely attacks poultry of any kind; this has been proven by the Department of Agriculture's investigation into the matter.

In addition to the excellent display of hawks at the American Museum of Natural History there is also in the Metropolitan Museum of Art a unique exhibit in the arms armor department, that of a falcon resting upon a mailed gauntlet. The armor is Saxon, of the late sixteenth century, and is evidently a ceremonial piece to be worn at royal functions. The steel on the knuckle plate is beautifully engraved, and a small spool is affixed to retain the falcon's leash, which is attached to the falcon's leg, the leg being encircle by a metal band, and not by jesses as would be the case were the bird in readiness for the hunt.

With the characteristic care for detail shown by the taxidermist department of the American Museum of Natural History, the gerfalcon is shown on his "block," a device used where falcons are kept, so that they may be put out in safety from the

Courtesy, Amer. Mus. of Nat'l Hist.
GERFALCON (THE ROYAL FALCON) ON HIS AIRING BLOCK

hawk house for their daily sunning and occasional bath. These blocks, which are practically wood stumps of comfortable resting size for the bird who is to use them, are undercut about six inches from the top in order that the leash may be made fast and yet revolve freely so as not to entangle the bird in his limited movements. Great care is taken in all matters pertaining to the hunting falcon that his feet be kept in good condition as they are one of his chief weapons; with his feet damaged he would be of little use.

That falconry has for many years flourished extensively in India is well known, the Maharajas and princes of native birth have been keen enthusiasts of the sport and it was only natural that the sport-loving officers of the British army, quartered in India, should take their share in participating in so pleasant a pastime.

There are many countries in which the pleasure of hawk hunting might well be cultivated and not the least important among them is our own land, America, where game is plentiful in the north, south, east and west, and yearly the tide is turning more devotedly to the sports afield both among our women and our men. Falconry, like golf, takes one into the open for healthful exercise without any call for overexertion on the part of its participants. The hawks we have, some of them but a few miles from our largest cities, as is instanced by one of the accompanying illustrations. All that is required is the skill in taking the passage bird, or obtaining the "eyess" from their eyrie, and the patience, which is above all things essential in the schooling of birds for the purpose of hunting. At first it might be necessary to employ the aid of professional falconers, just as in the early days of golf we depended largely upon the Scotch professional at our clubs to teach the art of golf, but time would in falconry prove as it has done in golf, that the American is quick to learn, and a keen enthusiast in any new pastime he takes up, falconry would prove no exception to the rule.

The Voluntary Determination of Sex[*]

The Factors Which Determine the Development of Male and Female Animals

By Dr. Koehler

A WOMAN of intelligence recently made the announcement among a circle of cultivated people that during a sojourn in the country she had learned how to obtain cocks or pullets at will from incubator chickens. The secret was as follows: The eggs to be incubated are laid upon a table and a horseshoe magnet is then suspended above them; it is alleged that those eggs above which the magnet hangs horizontally will produce pullets, whereas those above which it describes a conical figure will produce cocks. The instance is cited merely to show how little knowledge there is, even among educated people, with respect to recent investigations concerning the factors which determine sex in animals. It is worth while, therefore, to discuss the matter briefly.

The basic question is whether it is actually possible to determine sex—it is now safe to say that this question can be answered in the affirmative. In the second portion of this article we shall describe two actual instances in which it has been proved possible to make a voluntary determination of the sex of certain animals. But before these can be comprehended certain preliminary facts must be in the possession of the reader; hence we shall first endeavor to answer the two questions: How is sex determined in the natural process of bisexual procreation? What is the reason that one child of the same parents is male while another one is female?

We shall proceed from the basic principle that sex is *inherited*. Inheritance means that the properties of the parents are transmitted to the offspring by means of sex cells: When the male and the female trout have deposited their respective reproductive cells in the water, their function is fulfilled. The parent fish swim away but the cells of opposite nature which they have discharged into the water are attracted to each other, so that the egg cell is fertilized by the male cell and develops into a perfect fish. In this young fish all the characteristic features which marked the parents make their appearance. It is evident that the germs of these characteristics must have been contained in the sex cells of different nature, whose union led to the development of the perfect trout. We term these elements in the original cells inheritable characteristics, and it is through the operation of these that the characteristic features of the parents make their reappearance in the offspring.

Now the parents of the new-born fish were exactly alike except in certain specific features. Thus when a child is born of a white man and a negress both parents are human beings, but they are of different races and differ in certain respects such as color of skin, kind of hair, etc. The question arises in both cases: Since the parents possess certain different characters how will these be transmitted to the progeny?

MENDEL'S DISCOVERY

The fundamental principles discovered by Mendel enable us to answer this question: The causes of all the phenomena exhibited in inheritance are to be found in the behavior of the inheritable qualities in the sex cells, and we are enabled to form conclusions concerning them from the data observed.

Mendel crossed different kinds of peas such as red flowered ones with white flowered ones; the resulting offspring without exception produced red blossoms. When these were propagated through self fertilization, which corresponds to close "inbreeding" among animals of different sexes, then the progeny, *i.e.*, the hybrids of the second generation, produce 75 per cent of red blossomed plants and 25 per cent of white blossomed plants. The essential feature of these and later phenomena consists in the constantly recurring definite proportions, and a closer examination of the matter has led to the following conclusion: *Every living creature possesses two units of inheritance for each of its characteristic features* (our hybrid of the first generation, for example, included the units white and red for the characteristic flower color); one of these units is derived from the maternal egg cell and the other from the paternal seminal cell. In the example cited this hybrid had red flowers, *i.e.*, although it possessed both a white and a red unit of inheritance, only one of these units, namely, the stronger of the two, made its appearance in the hybrid. This fact is expressed by saying that the red predominates over the white, or, in other words, that the red is a dominant character while the white is a recessive character. When this hybrid produces sex cells in its turn, these cells are of both kinds and it forms an equal number of each; half of its sex cells carry the red unit of inheritance and the other half carry the white unit. This holds true of both sexes; when they are coupled (the self fertilization of the first red blossomed hybrid generation) it is quite possible that red egg cells may unite with either red or white sperm cells, and on the other hand white egg cells or *ova* may unite with either red or white sperm cells. If we represent the units of inheritance by letters of the alphabet, letting R equal red and r equal white, we shall obtain the following four kinds of fertilized egg cells: *RR*, *Rr*, *rR*, *rr*, and likewise an equal number of each kind, since in each sex the red and the white sex cells were equal in number. Since *R* predominates over small *r* it is evident that *RR*, *Rr*, *rR*, *i.e.*, three-quarters of a second generation of hybrids will produce red flowers, whereas only one-fourth of them, namely, *rr*, will produce white flowers, which theoretical estimate has been found to correspond to the facts.

UNITS OF INHERITANCE

What takes place then when we recross the red flowering hybrid *Rr* with the white flowering parent pea-vine *rr?* The hybrid possesses, with respect to color, the two different units of inheritance *Rr;* such organisms, which possess *two different units of inheritance*, are said to be *heterozygotic*. But the hybrid also forms, as we have seen, the sex cells *R* and *r* in equal numbers, and in exactly the same way each other heterozygote also forms equal numbers of two sorts of sex cells of the character in question. The parent plant, on the other hand, forms only the single kind of sex cell *r* since it has two *like* units of inheritance for the said character (*i.e.*, the flower color). Such organisms as possess *two like units* for a character are said to be *homozygotic;* in the reverse crossing itself consequently there may be united either the sex cells *R* or the sex cells *r* of the heterozygotes, or with the sex cells *r* of the homozygotes; hence we shall have the pea plants *Rr* and *rr* and an equal number of each. In other words fifty per cent of the new plants will bear red blossoms and the rest of them white blossoms.

But it is a general fact in nature, both among human beings and in the majority of animals, that an equal number of males and females are produced; this circumstance suggested that this peculiar mathematical relation of half and half in their progeny might be explained in the same manner as the reverse crossing described above. If this be true it is at once obvious that one sex must be heterozygotic, while the other exhibits recessive homozygotism. Let us suppose that the male sex is heterozygotic; in this case we can describe it by the inherit-

[*]Translated from *Die Umschau* (Frankfurt) August 14, 1920.

ance formula Mm. *M* signifies *male* and small *m female*, and the former predominates over the latter. In this case the female sex will have the inheritance formula *mm*. The male sex cells are of the two kinds *Mm* while the female sex cells or *ova* are all of the same sort, namely, *m*. When now any union occurs between the ovum and a male cell, according to the laws of chance, whether one or the other combination occurs it will be seen that in each of the two groups the number of elements is equal, *i.e.*, there must be as many animals *Mm* as animals *mm*—*i.e.*, there will be fifty males and fifty females. Naturally the same laws hold good if we assume that the female sex is heterozygotic: Let us in this case designate the inheritance formula of the female as *Ff* and that of the male as *ff;* here *F* indicates female and *f* male and *F* predominates over *f*. In both cases we have a definite reason why the relation of the sexes remains unaltered from generation to generation, since it is obvious that here, too, the final combination of the various elements would result in an equal number of males and females.

In the case of any given kind of animal it is possible to determine which sex is the heterozygotic form in cases of the so-called "limited sex inheritance." This is because of the circumstance that some special character of the organism makes its appearance in only one of the two sexes; thus it might occur that in the crossing of a red-eyed male fly with a white-eyed female fly all the female hybrids would have red eyes and all the male hybrids white eyes; thus all of the sons "take after" the mother and all the daughters after the father; whereas in a non-sex-limited inheritance both sons and daughters are either white-eyed or red-eyed. An enormous number of experiments along this line was found to be explicable only upon the assumption that in these flies the males were heterozygotes whereas the females were recessive homozygotes. Equally numerous experiments have shown that in th case of butterflies the state of affairs is contrary, *i.e.*, the females are heterozygotic.

CHROMOSOMES IN THE CELL NUCLEUS

A second explanation of the matter takes entirely different premises for its starting point. If we examine the egg cell or ovum in the microscope we see a small mass of living substance, the protoplasm, and within this is a vesicle known as the nucleus. And just as all of the cells which compose our body are produced by the divisions of the egg cell, each one of them contains a nucleus, whose origin is to be found likewise in the division of the nucleus of the egg cell. But at the time when this development of the egg cell began it had been penetrated by a male cell, whereupon a union took place between the nuclei of the male and the female cells—this union being known as fertilization. In preparation for division there appear in the nucleus certain bodies known as *chromosomes*, because of their strong affinity for *colors* or dyes. These often possess a rod-like form *and their number is constant in any given kind of plant or animal.* When the division of the nucleus takes place, each chromosome splits lengthwise into two portions, and each daughter nucleus contains one-half of each chromosome. *Thus the number of chromosomes remains the same in each division of the nucleus.*

But when sex cells are formed the aforesaid longitudinal division of the chromosomes ceases at a certain point in the progress of the division and undivided or *entire* chromosomes are distributed among the daughter nuclei. Because of this the nucleus of the sex cells contains only half as many chromosomes as does the nucleus of one of the ordinary cells of the body. But when fertilization occurs, the normal number of chromosomes is of course restored. Thus each of the ordinary cells which compose the body of a human being contains 24 chromosomes, whereas the sex cells of either sex contains only 12 chromosomes each. When fertilization occurs the 12 chromosomes in the egg cell of the one parent are united with the 12 chromosomes in the specific sex cell of the other parent so that the fructified ovum now contains 24 chromosomes.

Among certain animals one sex always has one chromosome more than the other sex; *e.g.*, the female of the thread-worm *Ancyracamthus* is characterized by 12 chromosomes, while the male has only 11. All of the ova of the former contain 6 chromosomes, whereas 50 per cent of the male sex cells likewise contain 6 chromosomes, the remaining half containing only 5 chromosomes. In case the ovum is fertilized by a male cell of the latter kind the resulting embryo will contain 11 chromosomes and will therefore develop into a male. But if fructification be accomplished by one of the former kind the embryo will contain 12 chromosomes and will consequently produce a female. Here again we shall have an equal number of males and females produced, since the two kinds of male cells are equal in number.

Organisms like this, which produce two kinds of sex cells in equal numbers, are termed *heterogametic*, while those which form only one sort of sex cell are said to be *homogametic*.

As we see in those cases in which the heterozygotism of the male was disclosed by the sex-limited inheritance, the male also forms two kinds of sex cells which differ from each other with respect to their chromosomes (the above cited case of the flies). Where, on the contrary, it is the female that is heterozygomic (as in the case of the butterfly), the egg cells or ova are of two kinds as regards their content of chromosomes, whereas the male sex cells are all alike. These facts may be expressed in other words, to wit: Homozygotism and homogametism (as likewise heterozygotism and heterogametism) always go hand in hand. The knowledge of these results has led to the conclusion that all the facts concerned can be reduced to a uniform formula. If we transfer the inheritance factors of Mendel's theory to the chromosomes, and thus we perceive that both of these ways of explaining the method of natural bi-sexual reproduction, *i.e.*, the theory of inheritance factors (the scheme of homo-hetero-zygotism) and the theory of chromosomes (the scheme of homo-heterogametism) really coincide with each other—both are merely different forms of expression of the same relationship.

Both of these schemes have one thing in common, namely, they explain only the half and half production of the two sexes; consequently the objection is raised that this theory could not serve as a basis for those relations of the sexes where unequal numbers of males and females are born—it was objected especially that this theory was utterly unable to explain the appearance of hermaphrodites—as a matter of fact, however, it is precisely such cases of hermaphrodites and of uneven numbers of offspring which furnish the most beautiful confirmation of the theory, since it is found that in every instance the relation of the chromosomes corresponds in the most remarkable manner with the specific nature of the reproduction. For example, let us point out that the hermaphrodite of the thread worm *Rhabditis nigrovenosa* contains twelve chromosomes like the separate sexed female and its eggs consequently contain six chromosomes. When, however, it forms male sex cells then one of the twelve chromosomes does not share in the process of nucleus division but remains inert, while the remaining eleven are distributed in the male sex cells in the ratio of 6 to 5, as a consequence of which male and female embryos are produced in the same number. Thus a hermaphrodite generation must inevitably be followed by one of separate sexes, whose reproductive cells will behave as just described. But their union will result in a new generation of hermaphrodites for the very reason that one-half of the male sex cells of the separate sexed generation, namely, those producing males, remain in this case non-fertilizing. As we see, the chromosome is not fitted for this under the operation of the laws inherent in the chromosomes themselves; far rather is it true that superordinate factors are present which are responsible for the fact that at the given instant a chromosome is simply cut out, or for which half of the male sex cells is condemned to remain non-fruitful.

The scheme of homo-hetero-gametism remains therefore valid, but not rigid and unalterable—merely capable of being

modified by superordinate factors, and this enables us *for the first time to conceive the hope that we shall be able to exert voluntary sex determinations.* If we succeed in gaining control of the superordinate factors, then it will undoubtedly be possible to produce one or the other sex at will.

There is still a second theoretic possibility, to represent which the Mendelian mode of expression may be employed. We had assumed that F is stronger than f and had assumed also that one pair of inheritance characters determines all differences of sex. In reality, however, it may be that a number of pairs of inheritance characters are demanded, and there are many signs which support the view that the relation of strength between these, instead of being constant, as in the case of the red and white pea, red pea blossoms, may be alterable upon occasion. In such cases we are accustomed to speak of *deferred dominance.*

AN INSTANCE OF VOLUNTARY DETERMINATION OF SEX

Being now provided with the indispensable information concerning the essential character of the natural determination of sex, we shall be able to comprehend the two instances which are thus far the only ones known, in which a voluntary determination of sex has undoubtedly been accomplished.

The female of *Bonellia viridis*, a worm-like creature classed among the transition animals possesses a body about the size of a walnut, which is provided with a proboscis measuring about 20 cm. in length. The male is microscopical in size and lives as a parasite in the uterus of the female, where the fertilization of the eggs takes place. The larvæ which hatch from these eggs are neuter creatures, possessing no sexual character. In studying these animals Baltzer found that if he placed an aged *Bonnellia* female in the dish containing these neuter larvæ, in the course of a few days all of the latter descended to the proboscis of the female, and after about a week developed into males which at once wandered away to their destined location. If, on the other hand, Baltzer kept these neuter larvæ at a distance from any mature female, then in the course of abouf a month nearly all of them developed into females, not more than 7 per cent becoming males. Finally, Baltzer was able to produce double-sexed or hermaphrodite animals at will by the following process: From one-half to two days after the larvæ had attached themselves to the chosen location, he detached them from the proboscis and continued to rear them in a free living condition. The longer they had remained attached the stronger the male characters became and the weaker the female characters. A more beautiful example of success in the effort to determine sex at will cannot be imagined.

Undoubtedly all of the neuter larvæ must have possessed not only the entire male equipment but also the entire female equipment, since according to the external conditions which prevailed they developed either exclusively into males or almost exclusively into females. The comparative vigor of the male and female equipment varies in the following manner: In the first eight days the male characters are more vigorous but later their strength decreases while, on the other hand, that of the female characters becomes greater, until, after a certain period of time, during wich the two sets of characteristics are equally strong, the female characters finally gain the upper hand. The manner of life attached to the proboscis, however, has the effect of accelerating the development in such a way that the entire time of development of those larvæ which are earliest attached is comprised in that portion of time when the male features predominate. In the same manner the female and hermaphrodite forms can undoubtedly be explained upon the ground of the assumed postponement of predominance.

EFFECT OF COLD ON SEX OF FROGS

The experiments made by R. Hertwig with respect to the effects of cold upon frogs indicates similar relations. While the frog larvæ which were kept at ordinary temperatures developed into equal numbers of males and females when they were reared in the cold, 30 per cent of the females developed into females, so that at the end of the experiment 86 per cent of the animals were males.

Even more striking results were obtained by Hertwig however in his researches concerning super-maturity in frogs, which experiments indicate methods of determining sex at will. It is a well-known custom of the male frog to compress the thorax of the female between his thumb calluses and this pressure occasions the release of the eggs. As soon as the eggs make their appearance in the water they are fertilized. Hertwig allowed one issue of eggs to be thus laid and fertilized and thereupon separated the parent animals, whereupon the laying of the eggs was at once checked. Twenty-four hours later he put the animals together again and separated them anew after a second deposit of eggs had been made; he repeated this process on the third and the fourth day. The four deposits of eggs exhibited the following results. From the first 50 per cent of males developed, from the second 65 per cent, from the third 85 per cent, while from the fourth there were 100 per cent. This experiment was frequently repeated with the same results. Thus the normal breeding in an experiment by Kuschakewitsch produced 58 males and 43 females; from the remainder of the eggs, which were deposited four days later, there developed 433 males and one hermaphrodite, only 17 of the eggs failing to develop at all. These results rivaled Baltzer's in the striking proof they offer of the entire possibility of the voluntary determination of sex.

As may be seen from a series of control experiments the cause of this change of sex is to be sought in the deferred fertilization of the eggs. Hertwig termed this super-aging of the eggs extra maturity, and it is evident that this is here the controlling factor. The final division of the frog egg does not occur till the egg enters the water, consequently a delay of four days meant a considerable degree of extra maturity; it is obvious, therefore, that this extra maturity controls the process of the division of the chromosomes, and correspondingly the distribution of the hereditary factors, in such a manner that only males are produced. While, however, the result of voluntary sex determination is the same in the frog and in the *Bonellia*, yet the methods by which this result is obtained are essentially different. In the case of the *Bonellia* we have a given complex of hereditary factors whose effectiveness exhibits a contrary relation with the lapse of time; the voluntary determination of sex is made possible by the fact that the rapidity of the development can be altered by man through the choice of suitable rearing conditions. In frogs, on the other hand, the state of the hereditary factor is alterable and it can be changed by making use of the fact of its dependence upon the age of the eggs. We recognize here that its essential nature consists in certain chemical transformations due to the increasing age of the eggs.

No further results so far as I know have as yet followed the rich promise of these beginnings. But now that the ice is broken it is obvious that it is well worth the trouble to experiment with respect to the voluntary determination of sex upon valuable species of domestic animals and plants. The practical value of this is evident, and on the other hand we need not fear that the veil of mystery, as far as regards humanity, will be early lifted, for there are innumerable reasons why man is not suitable to be employed as an experimental animal, and whatever analogies may be found they can be merely suggestive because of the manifold variety of biological conditions which governs the existence of every kind of animal.

OSTRICH EGGS AS FOOD

MR. GALLICHAN, diet expert, who has been experimenting with ostrich eggs supplied by the New York Zoölogical Gardens, declares that the food value of the ostrich egg is about the same as that of the domestic hen's egg. The flavor is identical, and although the ostrich eggs contain less protein than meat, they have more fat and a fair amount of phosphorous and iron. One egg will make an omelet sufficient for thirty people.

Termites of the Temperate Zone

A Study of the American Cousins of the African "White Ants"

MOST of us remember from our primary school days pictures of the conical structures shaped like bee hives made by the devastating African insects known as white ants, and when we recall the gruesome stories of the sweeping destruction, not only of food, but of books, clothing, furniture, and even houses, of which these obnoxious little creatures are guilty, we thank our stars that our own land is not cursed with them. As a matter of fact, however, there are certain first cousins of these insects known as the Nearctic Termites which already have a considerable foothold in this country, and which may be expected to extend their territory unless measures are taken to exterminate them, or at least to reduce their numbers.

For the following account of these dangerous but interesting little creatures we are indebted to a bulletin issued by the Smithsonian Institution and prepared by Mr. Nathan Banks of the Museum of Comparative Zoölogy, Cambridge, Mass., and Mr. Thomas E. Snyder of the Branch of Forest Entymology of the Bureau of Entymology, in the Department of Agriculture.

GENERAL STRUCTURE OF TERMITES

The termites are social insects of the class of Neuropteroids and live in moderately large colonies. They are commonly called "white ants" because of their pale color and their gregarious habits. Three castes are found—a winged caste which is always present and besides this usually a worker caste and a soldier caste. The winged caste consists of adult males and females. The soldier caste occurs in all genera except *Anoplotermes* and originates from the young of both sexes; occasionally they show traces of wings. The worker caste occurs in all except the Kalotermitidæ; they are small, wingless and usually blind.

After a flight the winged female breaks off her wings and starts a colony. She is now known as the Queen-Mother, and her body is enlarged with eggs. In some species these "true" queens are very rare, or at least hard to find. Sometimes indeed, "nymphs" become fertile without acquiring wings. Females of one of these forms may be present in colonies with males or "true kings." Thus we see that each colony of termites may have from five to seven forms besides the young of the species. However, the winged form may be considered as pre-eminently representing the species. Furthermore, the soldier is usually more or less characteristic for each species.

The adult insect has a flattened head which is truncate in front and rounded behind and which is nearly or quite as broad as it is long. The eyes are compound and near the front. There are slender moniliform antennæ containing twelve to twenty-five or more joints and rising from antennal fossa situated in front of the eye. The mandibles are short and the inner edge has several teeth, but the two jaws are not toothed alike. The maxillæ end in two horned curved points. In most forms there is an ocellus close to each eye and in fully one-half the species there is a more or less distinct aperture in the middle of the face, which is the opening of the frontal gland. This gland is known as the fontanelle of the fenestra; the secretion of this gland is utilized as a means of defense.

The prothorax is sharply divided from the rest of the thorax. The abdomen consists of ten segments, the first of which is indistinct or absent below. The wings are much longer than the body and are several times as long as they are broad. They usually exhibit very few veins but in some forms there is an irregular network of cross-veinlets. Near the base there is a more or less distinct transverse impression. It is at this point that the insect breaks off the wings after the flight. Both the body and the wings bear hairs.

The Soldier.—In the soldier the head is enlarged and usually elongated. Most of them have no eyes. In those species which inhabit wood the legs are usually short, while in the species that wander about the legs are long and slender.

There are at present 19 described species of American termites and 17 species and a variety new to science. The early divisions of *Termes* were based on adult structures and outline the groups known as sub families. In 1897 Wasmann declared the soldier ant to be highly important as a basis of division, but modern authors consider the matured winged insect to which is entrusted the future of the species to form the best basis of classification. It retains more of those minute ancestral characters which indicate relationship and, furthermore, it is the parent of both the winged form and the soldier. The best characters for group classification are found in the wings, head, legs and cerci.

DISTRIBUTION

Termites are widely distributed throughout the world, but exist in comparatively few species and genera. They can be traced back in geological times to the tertiary age. It is believed that some species may be found in every one of the United States, and they have been found as far north as Quesnal Lake in British Columbia, as well as in the northern States of Washington, Idaho, Montana and Maine. Furthermore, they have been found in the Rocky Mountains and the Pacific Coast range at such remarkable altitudes as 7,000 to 8,000 feet. Many of the 36 species now known in the United States have probably been "introduced" and authorities upon the subject warn us that various other species, native to the south of us, are liable to be introduced, particularly the destructive *Leucotermes tenuis* of the Bahamas and South America.

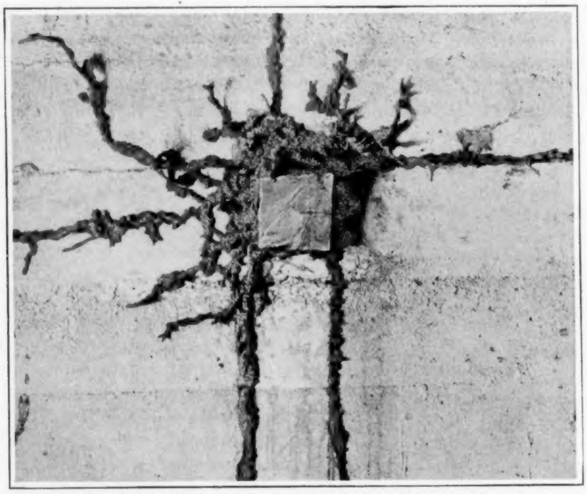
VARIOUS GROUPS OF TERMITES

Unlike some of the tropical termites our native species do not build nests in the form of huge mounds, but live in burrows made either in the wood or in the earth. Furthermore, there is no permanent "royal cell" containing an imprisoned "king" and "queen," and there are no so-called "fungus gardens" or "nurseries." Nevertheless the nests or colonies of our native termites are well worth study and are even more interesting because they concern us more nearly than those of tropical species.

They are divided by their habits into three groups: those species which live in wood but do not burrow in the ground; those which live in the ground and infest wood indirectly through the ground; and earth-inhabiting species which do not burrow in wood. Both of the latter groups are sometimes termed subterranean termites.

Subterranean Species.—The termites of this group belong to the family *Termitidæ*, subfamilies *Rhinotermitinæ* and *Termitinæ*. All of the species in the former subfamily of the genus *Reticulitermes* and some species of *Amitermes* are essentially wood destroyers and live in forests, building their nests either in the wood of dead trees, decaying logs and stumps, or in the foundation timbers of buildings, fences, and any other wood in contact with the ground, or else in a labyrinth of underground passages usually located underneath wood or vegetation. These subterranean termites are the most injurious to the timber, woodwork, and contents of buildings. The species of *Reticulitermes* even construct ingenious bridges across substances they cannot penetrate, such as metal or stone, brick or concrete. These bridges, as shown in an accompanying illustration, consists of small "shelter sheds" or granulated earth-like tubes constructed of earth and excrement extending upward from the ground. These tubes have been called the "adobe houses" of white ants. Some of these tubes

which were suspended from the infested wooden beams supporting the floor of one of the buildings of the Kansas State Agricultural College were 3 to 8 inches long and ended 2 or 3 feet above ground. Termites are soft-bodied creatures and always conceal themselves within the wood or within their tubes. In burrowing through wood they often completely honeycomb it, usually following the grain and eating out the soften thin-walled, larger-celled, new wood. But the species of *Reticuli Termes* are able to penetrate the hardest wood and even attack dry, seasoned wood provided there is access to moisture in the ground. They carry moisture with them, extending their galleries by means of moist excrement mixed with earth.



TUBES CONSTRUCTED BY RETICULITERMES HESPERUS ON WALL OF INFESTED BUILDING. LOS ANGELES, CALIFORNIA

The excavation is done by the workers which, as we have said, are blind and have soft bodies. It is often necessary for them to come above ground in order to obtain access to wood, and because of their nature they are peculiarly open to the attack of enemies when exposed; consequently they actually "take the ground out along with them" as Mr. Banks cleverly expresses it, either constructing covered run ways or tunnels by plastering earth upon the surface of the ground or else carrying moist earth into their galleries within wood. Thus they are enabled to travel far from the necessary moisture of the ground even up to the tops of trees or to the third floor of buildings.

Their Usefulness.—In spite of the damage they do to trees and houses subterranean termites are not without value. Prof. Henry Drummond, in his well-known work *Tropical Africa* compares their rôle to that of the earth worm in causing a constant circulation of earth, a sort of plowing and harrowing on a minute scale, "pellet by pellet, grain by grain." Furthermore, the vegetable substances eaten by them pass through their bodies and enrich the soil. Since these termites always require access to damp earth, a ready means of checking their depredation is to shut off the source of moisture, in which case they will not be able to extend their galleries and will perish.

In the Appalachian Mountains many colonies are found under stones while in Arizona some species also live in the wood, roots and stems of various species of cactus. In Kansas they live in large numbers in the heavily sodded prairie, existing on the roots of the vegetation. In Utah and Colorado they are found in the roots and stems of sage brush and scrub oak. The species of *Reticulitermes* readily migrate; they change their location within the nest according to the season, or with temporary changes in temperature or moisture, and if conditions are unfavorable the entire nest may be moved to a new site. Sometimes a single colony or nest extends into several adjacent stumps, trees, or logs. In regions where there is little or no wood, some species live in the roots or lower leaf rosettes of the agave and even in and under chips of dry cow manure.

All subterranean termites have a worker caste but no termite which does not live in the earth has such a caste with one exception, the *Prorhinotermes simplex* Hagen.

Wood Inhabiting Species.—Our native wood inhabiting species, which are non-subterranean, belong to both of the two families of nearctic termites, the *Kalotermitidæ* and *Termitidæ.*

The species of *Termopsis* live in the moist decaying wood of logs and stumps, usually inhabiting regions where coniferous trees predominate. They never leave the wood to burrow in the ground, and they infest the wood directly through holes under loose bark and decayed spots. So far as is known they are not particularly injurious, which is unusual among termites.

FOOD

The principal food of termites is cellulose and they obtain this from dead as well as from living vegetation. They can even be kept alive when fed merely on filter paper or cotton, according to Dr. Oshima, an expert zoölogist in the employ of the Government of Formosa. This authority has proved that when they eat the spring wood the hard lignin-cellulose is not digested, as can be verified by testing with hydrochloric acid, in which case the lignin reaction is obtained. The young are fed on prepared food from the mouths of the adult insects.

Excrement.—The excreted matter is very characteristic in different kinds of termites. In some it consists of rather solid pellets, compressed as shown in the accompanying picture; these sometimes fill the tunnels and are sometimes pushed out. In others the excrement is liquid and merely makes stains.

CHARACTER AND EXTENT OF DAMAGE DONE BY TERMITES

In 1876 Hagen made the statement that termites steadily retreat as the cultivation of fresh territory increases. Mr. Banks and Mr. Snyder, however, declare that this is only true in part. When their breeding places in dead trees, logs and stumps are destroyed, they infest fences, telephone poles, and the foundations and woodwork of *poorly constructed* buildings. Under these circumstances it is obvious that they may sometimes do even more damage than before. In fact, the damage done in the United States by termites to the woodwork of buildings and their contents, while not so great as in the tropics, occasions a serious amount of loss each year. The genus which causes the most damage is the *Reticulitermes*, but *Kalotermes* and *Cryptotermes* are also guilty.

They bore through books, paper, clothing, food and substances stored in dark and damp places, and even through shoes, as shown in one of the accompanying illustrations. They sometimes damage important documents and such injury has been especially noted in some of the department buildings in Washington. Many requests have been received in recent years by the Bureau of Entomology for advice as to the best method of getting rid of these insects, and it has often been found necessary to advise a reconstruction of the foundation and flooring of buildings, involving an expenditure of from $50 to $3,000. As information regarding the habits of these insects spreads among the public, it is probable that owners of houses will insist that contractors construct buildings in such a manner as to be proof against these ravages, which occur from coast to coast of our country, but are particularly serious in the South.

Termites do much damage to untreated wall board made from wood pulp and used for interior finish and also to telephone and telegraph poles, mine props, railroad ties, and other timber. A striking example of this is given in a report made by Mr. D. C. Palmer of the Bureau of Entomology: On the night of August 18th, 1916, southwestern Texas was swept by a typical West Indian storm, and this laid bare places where

termites had made nests in the bottom of the untreated telephone poles of some of the country lines, as also in nearly all of the wooden wind mill towers common in the country. It was a noticeable fact that *these wooden towers were blown down* whereas when steel towers were employed, only the mills themselves were wrecked and not the supporting towers. Termites also did much damage to crops which had been blown down and in a few cases where sorghum had been headed and the heads piled on the ground, the thrifty creatures had carefully covered them with dirt.

Termites also occasionally injure a great variety of living trees, bushes, shrubs, flowers, and field crops. They are especially bad in green houses since such buildings are always warm and moist, and untreated woodwork and growing plants are especially subject to attack. They injure flowers by tunneling and hollowing out the roots and stems.

REMEDIES AND PREVENTIVES

The two groups of termites, those that inhabit wood and those that inhabit earth, require to be dealt with in different ways.

Damage by Subterranean Termites.—It cannot be too strongly impressed upon the public that nearly all cases of damage to buildings by earth dwelling termites are due to poor or careless construction. The remedy is complete insulation or isolation of all untreated wood from the ground. Where possible buildings should be constructed entirely upon raised foundations of stone, brick or concrete, including stone columns or pillars in the basement to support the floor above. The walls and floors of basements and cellars should also be of concrete, and concrete floors should be laid on a gravel base. Basement window sills and frames should be laid over concrete in such a manner that the woodwork is prevented from coming in contact with the ground. Untreated timber should never be sunk either in the ground or in moist concrete, since otherwise termites may come up from subterranean galleries. Since complete dryness of the foundation and basement walls and floors is an important means of protecting buildings from attack, air spaces should be provided for between the ground and wooden flooring to hamper the activities of the termites.

Importance of Dryness.—Termites always require access to damp earth; hence if the source of moisture is cut off the insects will not be able to extend their galleries and will perish. This important fact should be made known and *emphasized* to owners of infested buildings, since this knowledge will save time and expense, especially in the case of old frame buildings where extensive repairs would be unwarranted. For example, if the source of ingress to the building be shut off by disconnecting the untreated foundation timbers from contact with the soil, the termites will inevitably die in the other woodwork, furniture, and stored material which they have infested, even in cases where they have penetrated as high as the second or third floor.

Protecting Living Plants.—Much injury to living trees, crops, flowers, etc., both in gardens and in greenhouses, can be prevented by clean cultivation and proper horticultural management. Injury is most common in the new soil of recently cleared woodland containing old stumps and wood or much leaf mold. Fence posts should be treated with coal tar creosote, and old boards or wood should not be left on the ground near fruit trees or in gardens. Prunings should be burned instead of being left on the ground and where termites are very destructive it is advisable not to use animal manure. Special care should be taken that living trees should not be scarred at the base.

NON-SUBTERRANEAN TERMITES

This simple method used in combating the subterranean species of shutting them off from their supply of moisture in the earth naturally cannot be applied to those who do not live in the earth and which include the genera *Kalotermes*, *Neotermes* and *Cryptotermes*, subfamily *Kalotermitinæ*. These require very little moisture and infest even dry wood directly through crevices, cracks, or decayed places. It is important, of course, to destroy their breeding places in decayed wood. Where these species are abundant windows and doors in buildings should be carefully screened, especially during the period of swarming or flight. During the swarm, the lights should be put out in unscreened buildings. When these termites have infested furniture, stored material, or exposed timbers of small size, they can be killed by fumigation with hydrocyanic gas. Since the species in these genera swarm at night and are attracted to lights in large numbers, the winged adults can be trapped by catching them in large shallow vessels full of oil or water, placed beneath lights. The unprotected woodwork of buildings should be treated with chemical wood preservatives.

FUNCTION OF THE AERIAL COLONIZING FLIGHT

When the winged sexual adult termites emerge and take flight, this process is merely a colonizing flight and, therefore, the terms "swarm" and "nuptial flight" are not appropriate. After a short flight the males and females alight on the

1. SHOE DAMAGED BY RETICULITERMES IN NORTH CAROLINA. 2 AND 3. DAMAGE BY RETICULITERMES FLAVIPES TO ROLL OF PAPER LABELS IN INFESTED BUILDING, AT BLOOMFIELD, NEW JERSEY

ground and separate into pairs (species of *Reticulitermes*) there is a marked attraction between the sexes, and the males follow the females about. The latter find a suitable site for the new colony and the pair become established. Not until after the pair are established in the new colony and the sexual organs have matured are they ready for breeding. Usually males and females from the same colony mate with each other, but sometimes they select individuals from nearby colonies swarming at the same time. The insects that have taken this flight never return to the parent colony, but form new colonies.

Usually the colonizing adults of the same species make their first flight, which is the largest in numbers, at the same time

DAMAGE BY KALOTERMES HUBBARDI TO RAFTERS IN "ADOBE" BUILDING IN ARIZONA

over a wide area of country. This annual production of winged adults in enormous numbers is undoubtedly intended for the further diffusion and perpetuation of the species, since this can be more readily accomplished by flight than through subterranean tunnels. Furthermore, places otherwise inaccessible can be reached. Unless carried by the wind they do not fly very far. Most of them, after a short vacillating flight, alight or fall to the ground and lose their wings. Some of them swarm during the day time and some at night. In buildings infested by termites the time of swarming is greatly influenced by artificial heat and the swarm from indoor infested timbers may take place a month or two earlier than outdoors.

COURTSHIP

Immediately before or after the loss of the wings a sort of courtship takes place in which the male follows the female tirelessly and persistently with his head close to her abdomen, which he touches with his antennæ. Often both run around a small circle and sometimes the pursued turns pursuer, apparently attracted by some secretion at the end of the body. Sometimes as many as three individuals may be seen running off together. In incipient colonies, after the first union, in case of species of *Reticulitermes* there is no further union until the first brood of young has matured, after which it is repeated at shorter intervals and more frequently throughout the life of the pair, for, unlike the honey bee, the male continues to live with his mate.

The reproductive forms are not necessarily monogamous; sometimes one male and two females or *vice versa* are found in the same cell, but these reproductive forms which have lost their wings are not normally polygamous as are the winged forms. The reproductive individuals of the second and third forms are always polygamous.

Eggs.—The rate of egg laying in the queens of nearctic termites is comparatively slow, unlike that of tropical species. Among our native termites none of the different forms of queens ever completely loses the power of locomotion on account of the distended abdomen, and they do not reach the enormous size attained by tropical species; hence there is no centrally located royal cell. In well established colonies of nearctic termites, tens of thousands of eggs are present, and allowing for an incubation period of ten days to two weeks, the rate of egg laying must be rather rapid, whereas in newly established colonies it is slow. Old mature queens lay continuously at least one dozen eggs in twenty-four hours. However, sometimes forty to one hundred reproductive individuals of the second form are present in the same colony. In the southeast of the United States in old long-established colonies of species of *Reticulitermes* egg laying takes place during the warm months, but in heated buildings they are produced in every month of the year.

The eggs occur in clusters and are tended by the young parent adults in the royal cell in incipient colonies. In long established colonies, on the contrary, the eggs are removed from the royal cell by the workers and deposited in the outlying galleries of the nest, where conditions are best suited for hatching. The eggs are yellowish white and reniform.

IMPRESSED PELLETS OF EXCREMENT OF KALOTERMES

METAMORPHOSIS

The newly hatched forms of all classes of termites were formerly consideraed to be alike or "undifferentiated," but the work of Thompson (1917) has disproved this. Thompson states that at the time of hatching there are two kinds of nymphs—the "reproductive" and the "worker-soldier" nymphs, which develop into the fertile or reproductive caste and into the sterile castes, and which may be distinguished by internal differences in the brain, the composite eyes, and the sex organs.

The metamorphosis of termites is of the type known as incomplete, or ametabolic, and in the case of the worker class there is very little external change during the development, except in size. The development of the worker is, therefore, a gradual growth, the semi-transparent, large-headed nymphs undergoing several molts preceded by quiescent stages.

In the soldier and "nasutus" caste the metamorphosis is marked by very considerable external and internal changes. Both workers and soldiers complete their development within one year. The development of the small-headed or reproductive nymphs is also very gradual, lasting about two years; it is marked by the external changes caused by the growth of the wings and wing pads.

CASTES OF TERMITES

The castes consist of the three types of reproductive forms and the wingless workers and soldiers which are normally sterile. The three reproductive castes are called, from the three types of nymphs which produce them, reproductive adults of the first, second and third form. In tropical species of some genera there are two different types of soldiers or more rarely of workers so there may be as many as seven different adult forms in the same colony. The commonest type is the de-alated, *i.e.*, denuded of the original wings, colonizing sexual adult, *i.e.*, an adult queen of the first form. These reach the largest dimensions and certain savages prize them highly as a delicacy. The abdomen of the male or "ring" also increases somewhat in size and it continues to live with the queen. Those males of the first form are very active, and on account of their small size they frequently manage to make a "clean get-a-way" when the nest is broken into. Sometimes, when avenues of escape are shut off the male will try to hide under the larger body of his consort, but usually, sad to say, he deserts her at the first sign of danger!

WORKERS AND SOLDIERS

The sterile castes consist of the worker and soldier or "nasutus" castes. They are produced by all three of the reproductive forms, and, unlike the bees, are of both sexes. The workers are all large-headed, but vary in shape and color. They do the "manual labor," so to speak, and do all the digging, besides caring for and protecting the royal couples and the young. In some genera, however, there are no true workers, their duties being performed by nymphs of the reproductive forms. The workers of the genus *Anoplotermes* are very singular in aspect and in their method of traveling in military files. The *Reticulitermes* also have the habit; they have a distinct and characteristic odor which may assist them in "following the leader"; however they may be aided by the tactile sense alone, according to some authorities.

Soldiers.—Soldiers are more highly specialized workers and also include both sexes. They are soft-bodied, but the head, which is pigmented, is reinforced by chitin. They are usually larger than the workers and in some species the mandibles are enormous!

In the genera *Constrictotermes* and *Nasutitermes* the soldiers have no mandibles, but there is a strikingly peculiar form known as the "nasutus" caste. The name is derived from the peculiar nose-like process or beak (*nasutus*). Liquid is exuded from this beak in defence, which reminds one of the use sometimes made of his trunk by an elephant.

The duty of soldiers appears to be entirely defensive but they do not appear to be highly efficient. Just before the time of swarming numerous soldiers and workers gather on the outskirts of the colony near the exit holes with their heads turned toward the exterior. But when the colony is opened and they are exposed to the attack of their great enemies, ants, the latter are easily victorious.

TROPHALLAXIS—A NEW THEORY OF BEHAVIOR

In connection with the workers' and soldiers' duties in the colony life a new theory has been recently evolved which is highly iconoclastic. The colony life of the so-called "social insects," bees, wasps, ants, and termites, has always excited interest and called forth praise, even from the times of Solomon and probably before. But modern entomologists who have "considered the ways of the ant" and become wise have struck a rude blow at their reputation for self-sacrificing and loving care of the queen and her multitudinous offspring. The new theory concerning the attention lavished by the workers on queen and brood is that it is entirely selfish! That it is due, in short, to a taste for the exudation from the bodies of the obects of their solicitude!

Mr. Nils Holmgren, who has devoted much study to the "exudate tissues" of termites, states that all the castes, but the queens in particular, have extensive exudate areas in the abdomen. This exudate passes through pores in the chitin to the surface, where it is greedily licked up by the other members of the colony. Holmgren, writing in 1909, stated his opinion that the exudate was not only the cause of the feeding of queen and brood but also the cause of caste differentiation. However the latter view has been disproved by Miss Thompson's work in 1917.

In 1918 Wheeler published a very remarkable paper on ant larvæ in which he boldly scouted what he calls the "anthropomorphic" idea of the behavior of ants. He suggests instead that it is due to an exchange of nourishment between the adults and the larvæ and he terms this coöperative relationship—a sort of mutual benefit society!—"trophallaxis." He admits however that this phenomenon has not been observed in the social bees. He makes the following interesting comments on this feature of the life of ants:

"If we confine out attention largely to the ants I believe it can be shown that trophallaxis, originally developed as a mutual trophic relation between the mother and her brood, has expanded with the growth of the colony like an ever-widening vortex till it involves, first, all the adults as well as the brood, and therefore the entire colony; second, a great number of species of alien insects that have managed to get a foothold in the nest as scavengers, predators or parasites (symphily); third, alien social insects, *i.e.*, other species of ants (social parasitism); fourth, alien insects that live outside the nest and are "milked" by the ants (trophobrosis); and fifth, certain plants which are visited or sometimes partly inhabited by the ants (phytophily)."

In the termite colony the workers and young nymphs may be seen scurrying off with eggs and young when the nest is disturbed. They not only solicit exudation from the queen but sedulously "clean," *i.e.*, lick, the bodies of other workers or nymphs, brushing them with the maxillary palpi. When the nest is broken into both workers and soldiers show alarm when near the reproduction forms by convulsive and jerky movements, which may possibly be meant for signals.

NATURAL ENEMIES OF TERMITES

Many kinds of animals prey on termites, especially at the time of the swarm. These include both birds and domestic fowls, lizards, spiders and crickets.

While termites and ants are commonly to be found inhabiting the same log or stump, yet ants are the worst enemies of termites. Ordinarily the relations between termites and ants are peaceful, even when they occupy contiguous galleries or actually intermingle. The ants seem to be indifferent to the presence of the termites until man breaks into the nests, when the ants soon attack the termites.

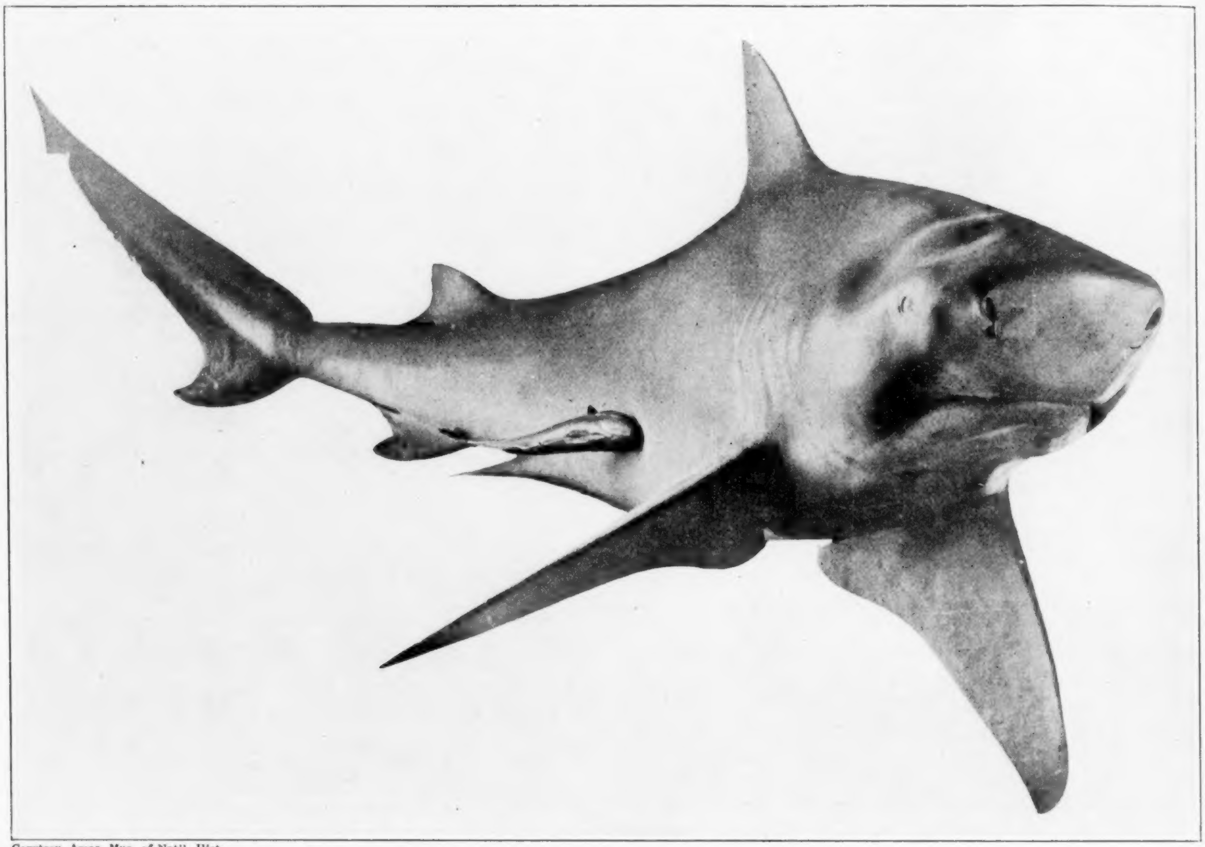
Species of *Cremastogaster*, *Camponotus*, and *Formica* are common associates of termites in eastern United States and are among the worst enemies of the soft-bodied termites. Living termites have been found in the mounds of *Formica* in Pennsylvania and Virginia.

The Argentine ant (*Iridomyrmex humilis*) is a great enemy of termites in New Orleans, Louisiana, according to Father A. Biever.

At the time of the annual swarm, ants kill and carry away many winged termites.

Beebe (1918) states that termites are immune to attack by the army ants of the tropics.

Other foes of termites are their parasites which include fungi, infusoria, protozoa and nematodes.



Courtesy, Amer. Mus. of Nat'l Hist.

MOUNTED SPECIMEN OF A REMORA ATTACHED TO A SHARK, ON EXHIBITION AT THE AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK

Fish That Are Trained to Catch Fish

The Remora, a Curious Fish with a Suction Disk by Which It Attaches Itself to Other Fish

By May Tevis

AMONG the most singular fishes to be found in the depths of the ocean are the various species of "shark-suckers" or remoras which fasten themselves to the surface of sharks or other fishes, allowing themselves to be carried about frequently to great distances. They attach themselves by a large sucking-disk on the top of the head, which is a modified spinal dorsal fin. They do not harm the shark, except possibly to retard its motion. If the shark is caught and drawn out of the water, these fishes often instantly let go and plunge into the sea, swimming away with great celerity.

So very queer looking are these fish, as the accompanying illustration shows, that persons not familiar with them generally mistake the back for the belly and imagine the fish is floating upside down.

The sucking-disk, whose partitions make it somewhat resemble the slats of a shutter, is capable of clinging with great tenacity, its action being due to the creation of a vacuum by the squeezing out the water between the lamellæ of the disk.

Because of the bulldog tenacity with which the remora hangs on to anything it has once laid hold of, it has been used by some native tribes to catch other fishes and turtles. One of the first accounts given of this unusual form of sport is from the pen of no less a person than Columbus, or at any rate from that of one of his companions. In a book published in 1671, Ogilby's "America," this ancient chronicle is quoted:

"Columbus from hence (that is, Cuba), proceeding on further Westward, discover'd a fruitful Coast, verging the Mouth of a River, whose Water runs Boyling into the Sea. Somewhat further he saw very strange fishes, especially of the *Guaican*, not unlike an Eel, but with an extraordinary great Head, over which hangs a skin like a bag. This Fish is the Native Fisher, for having a line or handsom Cord fastened about him, so soon as a Turtel or any other of his Prey comes above Water they give him Line; whereupon the *Guaican*, like an Arrow out of a Bowe, shoots towards the other Fish, and then gathering the Mouth of the Bag on his Head like a Purse-net, holds them so fast that he lets not loose till hal'd up out of the Water."

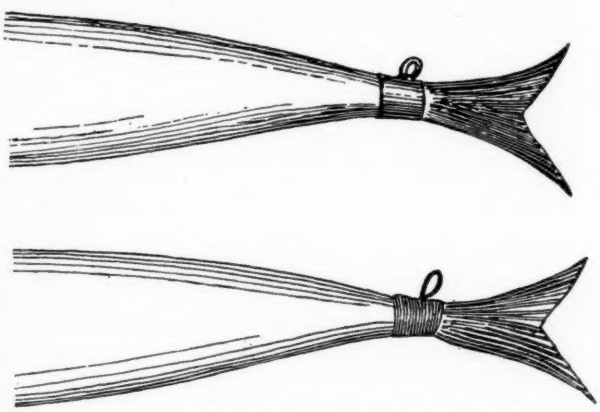
In 1884 an account was given of the mode of fishing adopted on the Zanzibar coast by the Africans with the remora. The account is by Mr. Frederick Holmwood, the British Consul at Zanzibar. It seems that the Africans fix a ring around the most slender part of the tail, which remains on for an indefinite period—sometimes for years—becoming imbedded in the flesh; to this ring the line is attached, and the fish are taken by the Africans on their cruisers, which last for a number of days, and slipped loose into the water when wanted; they then swim toward their destined captives, attach themselves and are hauled in, securing the fish for their master. The fact of their use in this way had been known long before; but no original account thereof had appeared for a long time. "When not in use," says Holmwood, "the fishes are mostly kept in small canoes or wells of water, and come to the surface on

the approach of the fisherman; and they have learned to allow themselves to be taken from the water and submit to being handled without attempting to plunge or break away. The owners are said to call them with a whistling sound, but whether they obey such a call or not has not been sufficiently verified."

The Zanzibar fishermen are as careful of their pet fishes and as tender with them as any huntsman of his favorite pointer or setter. They build tiny canoes for their homes, stroke them caressingly and talk to them confidentially.

HOW THE SUCKER DISK OPERATES

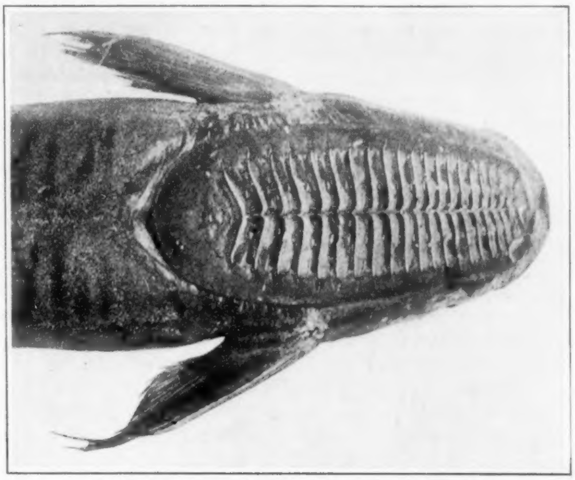
In the accompanying picture the sucking disk, situated on top of the head of the remora, is clearly shown. This picture was taken especially for the writer through the courtesy of Dr. Nichols and Dr. Fisher, of the American Museum of Natural History, from a specimen preserved in alcohol. Its structure consists of parallel lamellæ which are capable of being strongly contracted so as to form a more or less complete vacuum. When this is done of course the pressure of the water causes the disk to adhere with great force to the object against which it is pressed. Even in air the pressure exerted is very powerful. Dr. Townsend, the director of the New York Aquarium, recently showed the writer a picture showing one of these fishes, suspended by the tail in the air from the hand of the experimenter, lifting a bucket of water weighing about 25 pounds, although the fish itself was but little over 2 feet long. Many observers agree that at times the remora is actually torn apart, like the unfortunate travelers who were too short for Procrustes' bed, between the pull of a large fish in one direction and that of the master's cord in the other. This curious circumstance has led Mr. Mowbray to suggest that it is quite possible that the structure of the disk makes it impossible for the shark sucker to let go, when subjected to the pressure of the water and to the strain of a force pulling in the opposite direction. When the injuries are not too severe, the fish is capable of regenerating the lost part of its body, however. Yet when the remora is lifted above water while attached to a shark or other large object, it promptly lets go as soon as its head emerges into the air. Dr. Gudger of the Museum of Natural History, who has written a valuable monograph upon the nature and habits of this fish, relates that he has seen several remoras attached to the same shark. As the shark was gradually drawn out of the water the remoras dropped back from the surface of the water to take a fresh hold, repeating this operation several times.



TAIL OF A SUCKER-FISH WITH LOOP AND SERVINGS. (AFTER HOLMWOOD, 1884)

It should be said that the word *Remora* is applied to any one of several species of fish belonging to *Echeneis*, *Remora*, and allied genera.

Common American species of these sucking fish are the pegador, or remora which attaches itself to sharks (*Echeneis naucrates*) and the sword fish remora (*Remora brachyptera*). The writer has recently had the pleasure of observing some specimens of the remora in the New York Aquarium. These were the *Echeneis remora*, some 18 inches in length and handsomely marked with broad longitudinal stripes of black and white. Even in the aquarium these fish commonly cling fast to the wall of the tank.



CURIOUS SUCTION DISK OF THE REMORA

EFFECT OF MINERAL SALTS ON FRESH WATER FAUNA

IT has long been known that the waste substances discharged by many factories into nearby water courses, have a very deleterious and sometimes fatal effect upon the fish and other living organisms contained in such streams. The precise manner, however, in which such injuries have been caused has not been clearly understood. Various questions present themselves in this connection; for example, is the injury due to an alteration in the osmotic pressure, or to poisoning through mineral salts, and if the latter, is the toxic effect produced by a mixture of salts or by the ions of separate salts? A German biologist, Mr. E. Hirsch, has made an extensive study of these questions extending from 1912 to 1916. Some of the results obtained were published in the *Naturwissenschaften* (Berlin) for November 8th, 1918.

The subject is one of such importance from various aspects that we are glad to present an abstract of Dr. Hirsch's conclusions. His researches were carried on mainly in the Wipper in Thuringia. The first question was to determine whether the "salting" (in this case artificial in nature) of the river exerted any harmful effect upon the spread of different animals, and if so, the precise cause of such influence. The author reminds his readers that in all these investigations the capacity of fresh water fishes to exist and propagate themselves in waters to which salt has been added cannot be directly investigated. It must be remembered that any kind of fish is naturally dependent for its existence upon the food supplied by its environment; hence, any inquiry as to the injury done by mineral salts to the fish itself must be supplemented by an investigation as to the effect produced upon the plants or animals upon which it lives. The mineral salts which are present naturally in the waters of the river Wipper are not very significant. They amount to about 420 mg. per liter, with the high average natural hardness of 20 per cent, and consist chiefly of gypsum. At various points, however, waste waters from potash factories contaminate the river water, either through a direct discharge or by means of small affluents of the river. These wastes consist essentially of magnesium chloride, a mineral salt which considerably increases the hardness of the water and the total content of salt, but on the other hand considerably lessens the excess of gypsum.

The irregular distribution of the different kinds of animals in the region investigated indicates that a ***high percentage in the total amount of salts cannot possibly be a decisive factor*** with respect to the distribution of the animals for the reason that the organisms observed were found to be most largely present in exactly those portions of the river whose waters contained the highest percentages of mineral salts. Still another observation supports this conclusion. In the domain of the rivers lying near the Wipper, namely, the Bode and the Rhine, there is a remarkable lack of living creatures, although the salt content is considerably lower, even when the points where the catch was made corresponded hydrographically to the points in the Wipper. Since therefore local conditions cannot be regarded as the cause of the lack of denizens in the waters, this lack must be ascribed, doubtless, to the chemical condition of the water. But since these localities were much less well populated with fishes than others in the Wipper with almost double the percentage of salts, it is evident that in this case too the height of the percentage of the salt content cannot be regarded as a decisive factor, but *only as a peculiarity of its composition.*

This opinion receives strong support from the following considerations: the extensive investigations of J. Loeb and his school have indicated the toxic action of the separate ions of the salts and have also shown that this effect may be eliminated by the addition of some other ion (as an antidote). Thus sodium is made harmless by the addition of potassium and magnesium by that of calcium and vice versa. These facts and results of other experiments caused Mr. Hirsch to form the hypothesis that the injury received by the water fauna must be due to the *composition of the mixture of salts* contained in the river water. He came to the conclusion therefore that the mineral salts in fresh water must be to a certain degree "de-intoxicated." This of course is a counsel of perfection since it would hardly be possible to accomplish this outside the laboratory. It is evident, however, as a consequence of this theory that *the fauna of the water are injured by the ions of the non-neutralized excess of a salt,* but that this toxic action does not take place until the total concentration of the water reaches a certain degree which has not hitherto been precisely defined.

Practical experiments justified the theoretical conclusion; for instance, it was found that those brooks in a domain of the Wipper which were scantily populated contained an *extraordinarily great excess of calcium sulphate.* The marked predominance of the SO_4 over chlorine in other cases caused no especially noticeable damage to the fauna; hence it must be concluded that *the peculiar mixture relations of calcium and magnesium are responsible for the scanty numbers of the fish population.* This enables us to understand, likewise, the singular distribution of different kinds of animals in the Wipper. It was possible to demonstrate that a plentiful supply of water fauna begins to develop in the upper Wipper just at the point where there becomes perceptible a gradual neutralization of the considerable excess of calcium by means of the magnesium received in the waste waters from the potash works along the course of the river. Correspondingly it must be noted, however, that certain organisms diminish in proportion as the ratio of calcium to magnesium becomes such that there is an excess of the latter.

Dr. Hirsch refrains from claiming that these observations furnish a final definite answer to the question as to whether the injuries done to fresh water fauna through the presence of mineral salts is due to osmotic pressure or to the toxic effect of separate ions, but it certainly seems evident that the aforesaid toxic action is chiefly, if not entirely, concerned in the damage done.

THE MOUNTAIN PRIDE OF JAMAICA

THE two trees with the tall slender stems shown in the accompanying photograph are not palms as the casual observer might be led to believe. A little closer inspection shows that they are regular exogenous trees with well-developed bark and wood entirely unlike a true palm. There is probably no other hardwood tree that looks more like a palm than the Mountain Pride of Jamaica or so called Maiden Plum tree of the West Indies. The botanical name is *Spathelia simplex;* the generic name is from a Greek word meaning staff, having reference to the long slender stem and the specific term relates to the fact that the stem is always simple. The tree never develops branches and for this it is most remarkable. Like the cocoanut palm it invariably leans to one side which is due to the excessive weight of the numerous long leaves disposed closely at the top of the stem which is in many instances 50 feet high and only from 15 to 18 inches in circumference.

The leaves are pinnate and very variable both as to their size and character and to the general outline of the leaflets, which are disposed irregularly in from 20 to 40 pairs. The

THE MAIDEN PLUM TREE OF THE WEST INDIES

lower leaves are several feet long and droop, while those near the top or apex of the stem are much shorter and are frequently nearly erect. As the lower ones are shed, they leave triangular protuberant marks or scars on the stem which may be observed to run spirally around the trunk from the base to the top as in many of the palms.

While this tree has many features of interest both to the botanist and the layman, one of the most singular facts about it is, that it produces fruit only once in a life time and then dies. The large pyramidal flower cluster which grows from the very apex of the stem overtopping the leaves does not appear until the tree is from 8 to 10 years old. The large panicles of beautiful bright purple flowers may be seen at considerable distances as the trees usually overtop all others in the forest. The flowers develop rapidly into relatively small drupes resembling plums, hence the local name Maiden Plum tree.

As soon as the fruit is fully matured, the life of the tree appears to have been sapped away and it dies. The wood which is almost white and quite soft is never used and soon decays, leaving no trace of what a short time before was a thrifty looking tree attracting the attention of every passerby.

German War Substitutes*

Ingenuity Employed in Devising Substitutes for Products Cut Off by the Blockade

By A. Belter

THE ingenuity of the Germans was taxed to a high degree during the war to produce substitute technical and alimentary products to counteract the effect of the blockade which prevented them from importing many important and useful commodities. As a result many new industries were created of which we still possess only vague information. Substitutes for foods and different industrial substances were devised in large numbers and some of the more important of these will be described here.

A. FOODS

1. Meats.—The quality of sausages, which is used very largely by the Germans, decreased materially after the start of the war. Abattoir refuse was used for their manufacture to a far greater extent than before the war, but always under the supervision and control of the Government. Imported sausages, which sold at a very high price in spite of their poor quality, contained very large quantities of flour and water. There were also to be had preserved meats in imported boxes, which had to be heated before their contents could be eaten. According to Ruhle, for example (*Zeitschr* für Aug. Chem. 1916, I, page 369), a box, containing a pound of "ham with macaroni and tomato bouillon," had only 17.5 grams of ham in it. A pound can of "pork with sauerkraut" contained only 38 grams of meat.

Hundreds of substitutes for meats were manufactured which consisted for the most part of highly spiced and salted mixtures of ground cereals (maize, wheat, barley and rye) and potato meal or crushed nuts. Certain proportions of gelatinous substances were added to give the product the appearance of a jelly.

Fish was used with great success. The Germans were able to remove the peculiar fishy taste and give the product the taste and aspect of a large variety of meats. Spanish mackerel, for example, was made into ragouts, escalops, roasts, etc., and it was impossible to detect the fish in the dish. The law made the sellers of these preparations declare their true compositions.

Sausages were also made from the meat of fishes, crabs and mussels. These sausages could be eaten cold or in the form of a hot soup. Finally, the meat of cetaceous animals (whales, seals) was consumed in large quantities. Carefully guarded secret processes were used to remove the disagreeable fishy and oily taste from these preparations.

2. Extracts for Use in Soups.—Such products deteriorated in quality very rapidly. The extracts made from yeast were passable to the taste at first; then their content in yeast diminished more and more until they contained up to 60 per cent of common table salt.

3. Eggs.—Two kinds of mixtures were used as substitutes for eggs. One sort did not contain any albumen while the other contained some vegetable albumin or casein. The worst products, belonging to the first class, were nothing more than maize flour, colored yellow, to which some bicarbonate of soda was added, or a mixture of bicarbonate of soda and tartaric acid, or else some acid phosphate of calcium to give the product the suppleness of the natural egg.

4. Milk.—Condensed milk was consumed in large quantities. This was made from the whole milk or from whey with or without the addition of sugar. Foreign milk, sterilized in the bottle, was imported.

Various artificial milk powders were manufactured, some of which served their purpose very well. Others, on the other hand, did not emulsify with water readily or completely. The soldiers in the field used milk powder, which was compressed into the form of tablets. One of these powders, which proved to be very popular, consisted of a mixture of casein, fat, lactose and salts. When this was dissolved in hot water, it gave a product which had the appearance and composition of milk.

A creamy milk powder, which was sold under the name of "Lacto-preserve," was made in the following manner. Good pasteurized milk was subjected to the action of lactic acid ferments at 36°C. until a certain degree of acidity was obtained. The product was then evaporated to dryness in vacuo at 50°C. 1,600 grams of the pulverized residue were mixed with 300 grams of sugar, 100 grams of wheat flour and 20 grams of "roborat," a food consisting of pure vegetable albumin made from grains of wheat. The final product was a white meal which had the following composition: dry matter, 89.36%; albumin, 22.94%; fat, 11.28%; carbohydrates, 51.70%; salts, 5.05%. When 200 grams of this mixture are dissolved in a liter of water an emulsion is obtained which looks and tastes like a good fresh creamy milk. This beverage is very nutritious and can be used to good advantage by children and in the treatment of the diseases of the stomach and the intestines.

5. Butter.—Oleomargarine is a good substitute for butter, provided it is manufactured carefully and has a good taste. Cocoanut butter can replace ordinary butter in the kitchen equally as well. But the Germans soon depleted their supplies of these substances. To butter bread, mixtures of flour and casein were used. Fraudulently sold butter "ersatz" consisted of mixtures of flour and curdled milk. An "ersatz," called "Nova," was nothing more than potato meal, colored yellow and mixed with salt and magnesium sulphate. Another "ersatz," which had the appetizing appearance of a good yellow butter and which sold at 1.40 marks per pound, contained 17% fat, 13.5% potato flour, 5.5% of salt and 64% water.

6. Fats and Oils.—The almost total deficiency in the supply of fatty substances resulted in the search and discovery of new sources of supply which no one had thought of hitherto. An important development was the processing of that part of the cereal known as the germ, which contains about 12% of its weight in fat. Before the grain is ground the germs are removed by means of a special machine. In the case of wheat, the germ forms about 2 to 3% of the total weight and in the other grains it is about 1 to 1.5%. Based on an annual yield of 15 million tons of cereals in Germany in two crops, the germ production would amount to 100,000 to 150,000 tons which would yield about 10,000 tons of oil. After the fatty matter has been removed from the germ, the remainder can be used to good advantage as a food, because of its high content in albumin.

The substitute for salad oil was made from the viscous liquids extracted from plants, such as the marsh-mallow. The extract was colored yellow and spiced with a preparation made from cabbage and preserved by means of benzoate of soda. Emulsified solutions of gums, such as agar-agar were used as well. Oils were manufactured and are still being manufactured from the seeds of fruits and the kernels in the nuts of such fruits, as peaches, plums, etc.

These fruit stones are first crushed in special apparatus and the kernels are separated from the shells by means of a solution of calcium chloride or chloride of magnesium (density: 1.15). The kernels (density: 1.05) float on the surface of the liquid while the shells of the stones (density: 1.18) sink to the bottom. The kernels are then washed, dried and

*Translated from *l'Industrie Chimique*, 1920, pp. 112-114.

finally pressed in a hydraulic press to squeeze out the oil. Another process consists in reducing the stones to the state of a pulp and then extracting the oil by means of an appropriate solvent. The steam, which is used in recovering the solvent, frees the oil completely from hydrocyanic acid.

7. Sugar and Honey.—Properly speaking, there is no substitute for sugar. To sweeten marmalades, lemonades, etc., glucose or a glucose syrup was used. Saccharine is not sugar but only tastes like it and, as is well known, has not the nutritive value of sugar. The quantity used in sweetening a cup of coffee or tea is insignificant, as this coal tar derivative has 300 to 500 times the sweetening power of ordinary sugar itself. Saccharine can be used very well in beverages, but cannot be used in the preparation of jellies and like confections whose consistency is due to the sugar that is contained in them.

An artificial honey was also manufactured, but as the supply of sugar was very limited, the production did not amount to very much. The artificial honeys were made by converting sugar into invert sugar (an uncombined mixture of dextrose or glucose and levulose or fructose (fruit sugar). The sugar that was used was made from beets. To the product obtained as above, various coloring matters and aromatic substances were added.

Artificial honey powders were constituted of colored mixtures of cane sugar and acids for inversion (tartaric or citric acid). Furthermore, liquid inversion mixtures were sold as such, to which the purchaser himself was supposed to add the sugar. With two such mixtures, if the directions were followed implicitly, a syrup, having the exact taste and color of honey, was obtained.

8. Marmalades and Jellies.—Many mixtures were sold under these names which did not contain any natural fruit at all and which had about the same composition as the artificial honey powder (cane sugar and inversion acids). These preparations were colored and were incorporated with various aromatic substances to simulate the taste and appearance of the different fruits, such as apple, grape, strawberry, etc. The jelly powders were differentiated from the marmalade powders by a more or less large addition of gelatine.

9. Coffee.—No plants containing caffeine grow in Germany and all the various coffee substitutes did not contain that nerve stimulating alkaloid. The best that could be done was to manufacture bitter infusions which had the color of coffee and the most widely used of which were made from chickory, barley and rye. These preparations were consumed as such or added to real coffee. Other substances that were used at the very beginning for this purpose, but whose use ceased soon, due to depletion of the supply, were figs, date stones, carob-beans, which came from foreign countries and then beets, after their sugar content had been extracted. In addition, acorns, chestnuts, grapestones, turnip-cabbages were also employed to make coffee substitutes, but the "ersatz" that was appreciated most was made from malt. This preparation is still being used in large quantities. It has the aroma of coffee and is brewed from the roasted malt.

10. Tea.—In a similar manner the German flora do not contain any theine, which is the particular alkaloid that gives tea its characteristic taste and physiological properties. Various concoctions were prepared but none possessed the aroma and tonic effect of tea. The leaves of the small meadow rose, of the strawberry plant, of the blackberry, of moss, of the cherry tree, of German acacia, and of the black currant tree were used. Infusions, made with the dried berries of the hawthorne plant, were conserved in large quantities. The beverage had a very agreeable taste and the scent of vanilla.

11. Spices.—Most of the spices were imported, but as their use is only to flavor foods and as they do not themselves possess any nutritive value, the Germans could very well do without them. It may be remarked that one of the most esteemed spices, vanilla, was supplanted entirely by the synthetic vanilline.

B. TECHNICAL PRODUCTS

Very little indeed has been published on the various technical "ersatz" substitutes that the Germans used during the war. These substitutes must have been undoubtedly very numerous and very interesting and it is unfortunate that our knowledge of them is so limited.

1. Metals.—The imports of metals into Germany before the war were very large. Many of these were not found in Germany itself and still others, while native to the country, were not refined in sufficient quantities to satisfy the demands. At the beginning of the war the Germans had a considerable stock of all sorts of metals, in the raw state and as manufactured products. A classification of these metals, termed "Reserve Metals," was made from the military point of view, as follows: Copper, nickel, tin, chromium, tungsten, lead, zinc, antimony and aluminum. The strictest economy was practised in their use. Copper was replaced by zinc or aluminum. Very accurate tests proved that the alloys of copper are not absolutely indispensable, as was thought formerly in the manufacture of machines. Good results were obtained with iron or the iron alloys. Parts of machines, made from cast-iron, such as water or steam cylinders, were much more water-tight or steam-tight than when made from copper alloys, as the coefficient of expansion of cast iron is smaller than that of copper and its alloys. No one would have believed before the war that bearings for rapidly rotating shafts and axles could be made out of cast iron and give perfect satisfaction.

Iron replaced copper on a large scale in electrical installations, that is, for electrical conductors. Zinc was employed for the windings of dynamos and motors in spite of its relatively high electrical resistance.

Aluminum has been replacing copper more and more not only in Germany but elsewhere as well. Aluminum, alloyed with a few per cent of copper (the alloy can be machined more easily than the pure metal), was used first by the Americans in making howitzer shell fuses. The Germans also discovered a substitute for anti-friction or babbit metal, but nothing has appeared in their literature up to the present time concerning this interesting subject.

2. Gasoline and Benzine.—To clean garments and to dissolve greases, gasoline and benzine were replaced by carbon tetrachloride which possessed the great advantage of being incombustible. In a like manner the Germans used and still are using tetrachlor ethane, pentachlor ethane, trichlor ethylene and hexachlor ethane. All these products are obtained by the direct combination of acetylene with chlorine in the presence of catalysts. There is scarcely any difference between the cost of making these chlorine derivations and that of gasoline or benzine and in addition all of the former substances are inflammable. Furthermore they can be recovered without loss by distillation with steam, as their densities are such that they sink to the bottom of the watery liquid and evaporation is prevented thereby. However, ethane tetrachloride possesses the disadvantage of being poisonous when breathed in large quantities. When dry, these substances have no action on metals and trichlor ethylene does not attack metals even at the boiling point and in the presence of water. These products have been used in every increasing quantities in the industries as solvents of greases, resins, in the manufacture of varnishes, cellulose acetates, in the treatment of bones, beeswax, hair and skins, wool, cotton waste, stearin, casein, paraffin, oleaginous grains, sulphur, etc. Ethylene trichloride was employed in particular in the manufacture of explosives and the hexachloride proved very advantageous as a substitute for camphor in the fabrication of comparatively fireproof celluloid.

Gasolene and benzine, as motor fuels, were replaced with good results by mixtures of benzine and wood alcohol, or gasolene and wood alcohol, or acetone and wood alcohol. Because of the lack of coal, large quantities of combustible liquids were consumed. In many large factories, Diesel engines were operated on coal oil with very good results and at low cost.

3. Lubricants.—The supply of lubricants was conserved by mixing the oils with very finely divided graphite. The best products were obtained with colloidal graphite, such as is found in the commercial preparations known as "Collag" and "Oildag," which are themselves nothing more than mixtures of oils and graphite, intended for incorporation with lubricating greases. By the addition of 1 to 2 per cent graphite to the lubricating oil, a saving of 50 to 60 per cent in oil was effected. Soot was also used with great success. In certain cases pure graphite without any oil at all was found to be very effective. Lubricating oils and greases were made as well from fish oil and tar oil. An interesting fact is that the molasses, recovered in sugar refineries, was found to be an excellent lubricant.

4. Fats and Oils.—Due to the importance of these substances as lubricants, as raw materials in the manufacture of soaps, glycerine, stearin, greases, etc., the German chemists and technologists paid particular attention to the development of "ersatz" materials to take their place. Many interesting new processes were devised and much work was done in perfecting the old ones.

The chemist, Linder, found a new source for grease by cultivating a sort of barm which contained in the dry state 17.06 per cent fat and 31.40 per cent of protein matter. An oil is extracted from it and can be used in the manufacture of soap. A German patent was issued on the process of obtaining fatty substances by heating the refuse from fisheries, abattoir waste, etc., in autoclaves under pressure. The fecal refuse of cities and towns served as a source of fats and large quantities were thus made available. Such a process (Pick and Arnold) had already been used in the United States before the war.

The German patent (No. 145389) describes a process for the extraction of this fat by means of benzine. A clear product was recovered which had no odor and neither had the residues remaining after the extraction; they made a very good fertilizer. Another process (German patent No. 159170) consisted in saponifying the fecal matters with alkalies at the boiling point. The soap is leached out with water and then acidified to precipitate the fatty acids. These are then extracted by means of suitable solvents and are used either in the manufacture of candles or to make stearin.

Even before the war the recovery of grease from sewage had assumed considerable importance. Bechhold (*Chem. Ztg.*, 1915, p. 283) estimated that about 670,000 kilos. of grease were contained in the daily sewage production in Germany. In traveling from the kitchen to the city recovery pits, the diluted fats undergo a partial dissociation and a part of the glycerin is lost in this way. In order to avoid this loss, it was recommended that there be installed in each house a small recovery tank into which the sewage would first flow from the kitchen drains. The grease that is extracted from the mud that accumulates in these tanks is a dirty brown product. When subjected to distillation under reduced pressure, the impure grease yields a yellowish material, which separates into two parts when pressure is applied to it. Equal weights of olein and solidified stearin are obtained. The olein is used for lubricating purposes in spinning mills, in the manufacture of pharmaceutical pomades for the "toilette," and in making an inferior grade of soap, containing free olein, as for instance the soap that is used in tanneries. The residue that remains after the distillation of the crude grease is a sort of pitch which is employed in the insulation of electric cables, as a lubricating grease and also in the manufacture of roofing paper. The degreased and dehydrated mud deposits in the household tanks are used as a fuel or to make fertilizers.

5. Soap.—Soap was an esteemed luxury to the Germans during the war as may readily be imagined from the great deficiency in oils and fats. Before the processes, described in Section 4 above, were developed, a sort of soap was used under the name of "war soap," which did not contain more than a very small amount of fatty acids. For cleaning clothes, soap was replaced by soda ash (carbonate of soda), silicate of soda (water glass) and silicate of ammonia. Good results were obtained as well with oxygenated water and perborates (borax powders). A very curious product, called "burnus," contained a tryptic enzyme (compare trypsin, an enzyme found in the human intestines, where as is known the fats and oils are digested manly. *Abs*). This enzymetic substance was actually derived from certain human glands. It has the property, even when present in the most infinitesimal proportions, of decomposing the fats and albumins and rendering them soluble in water. Other soaps were made with clay as the basic substance. The active ingredient of this was the colloidal clay as it exists in finely powdered kaolin. Soaps were manufactured as well from kieselguhr (infusorial earth, as is used in making dynamites).

As a substitute for toilet soap a mixture of clay and a resin soap was used. Very often emulsive substances such as saponin (chemically this substance is known as a glucoside and possesses the property of emulsifying with water and preventing the precipitation of resinous matters. *Abs.*) and the washed residues from cellulose manufacture were added to these soaps. To clean the hands preparations containing powdered pumice, wood ashes, cinders, etc., found favor.

6. Glycerine.—The production of glycerine was curtailed seriously by the lack of fats and the gradual cessation of the manufacture of soap. Furthermore, all the glycerine that was made was used in the fabrication of explosives and the general public was forced to do without this substance. (Where the use of glycerine was primarily due to its inherent chemical properties, it was of course impossible to replace it. This was the case in the manufacture of explosives and as a result new processes were developed for making this substance. The most important of these was the manufacture of glycerine from molasses or sugar, either cane, fruit or grape. The ordinary fermentation process starting with a sugar yields alcohol. The process is conducted under such conditions that fermentation is not permitted to go to the alcohol stage, but is stopped at the aldehyde stage. This is accomplished by the addition of sodium sulphite and when this is done, glycerine is formed instead of alcohol. This glycerine is recovered by distillation. The process was and is being operated on a commercial scale. *Abs.*)

For some purposes it was satisfactory to use "ersatz" materials instead of the glycerine. In field kitchens, for example, glycerine, as the heating conductor, was replaced by vaseline, oil or by a low melting paraffin. To soothe chapped hands and face, as a viscous liquid capable of mixing with water, it was substituted by erythrite (or erythritol, a carbohydrate alcohol), as well as by certain salts of lactic acid, called perglycerine (lactate of soda) and perkaglycerine (lactate of potash). Many other substitutes for glycerine were nothing more than sirups made from ordinary sugar.

7. Rubber.—No plants have ever been found in Germany whose saps or juices could be used in the manufacture of rubber. Attempts have been and are still being dade to discover such a plant. The shortage of rubber was very acute. Automobile trucks for transporting men and supplies were furnished with specially made metallic wheels. It was a rare thing to see pneumatic tires on any vehicles or motorcycles.

Many processes were devised for regenerating old rubber and rubber waste of all sorts. Much attention was paid to the synthetic rubber industry. Rubber was made from isoprene, butadiene, and dimethybutadiene by the polymerization process, causing two or more molecules of these substances to combine. The great German dye and chemical house, the "Badische Anilin und Soda Fabrik," perfected a process during the war of producing these intermediate substances, which was fraught with great promises. Butadiene was made from benzine and phenol; isoprene from the three acyclic pentanes contained in low boiling gasoline. There is no lack of these raw materials in the world as the petroleum produced in the United States alone in 1913 contained 300,000 tons of these pentanes.

Several substitutes for rubber were developed, two of the most important of which are cited below:

A. The white "ersatz," which is obtained by the action of sulphur chloride (S_2Cl_2) on rape seed oil. When these two substances are permitted to react, there is formed an addition product of a pale yellow color, possessing almost the same physical properties as ordinary rubber, and containing about 6 to 8 per cent sulphur and the same proportion of chlorine. This product is insoluble in most of the organic solvents, but is saponified by caustic alkalies with loss of the chlorine.

B. The brown or black "ersatz," which is obtained by the action of sulphur at a higher temperature than in the first process on rape seed oil, previously oxydized by being heated in air. The product contains from 4 to 20 per cent sulphur, is insoluble in the organic solvents and is saponified by caustic alkalies, producing sulphur soaps. It was sold in the form of elastic slabs or as a reddish brown powder. Ebonite was replaced by a product called "Ernolith," which was formed by the action of formaldehyde on yeast and brewery refuse.

8. Leather.—The supply of leather was exhausted very soon after the suppression of the importation of hides. The slaughter of animals was reduced to a minimum and that coupled with the great amount of leather consumed by the army practically eliminated the use of leather by the general public. The development of substitutes to take its place was, therefore, of momentous importance.

The best "ersatz" was made from waste leather, very finely pulverized and pressed into sheets by the hydraulic press, with the incorporation of a binding agent. The pliability of the product was increased by the addiiton of oil. This was the first leather "ersatz" made, but, as the war progressed, other substitute products were manufactured, which contained but little if any leather at all. One of these "ersatz" materials was made by mixing together wool reduced to the state of a fine fuzz, cotton lint, wood pulp and a suitable binding agent, such as a strong glue or a solution of rubber. The sheet of "leather" made from this mixture was strengthened by the interposition of layers of fabric. Another process consisted of manufacturing very thin sheets of artificial leather which were then glued together with layers of fabric intervening between each sheet of "leather." Another "ersatz" was the product known as linoleum and called "peganoid." This was made from celluloid refuse, castor oil and a mineral coloring matter. Another leather substitute was produced by impregnating woolly fabrics with a solution of viscose or rubber. This last product possessed the advantage of resembling leather throughout its entire thickness. Later "ersatz" leathers were nothing more than cardboard impregnated with ordinary varnish or with celluloid varnish.

An artificial leather was made by treating hide waste with lime water until it began to decompose. This product was then washed carefully with water, the hair was removed in special grinders and the dehaired material treated in a bath of sulphate of zinc. The "ersatz" was dried finally in a vacuum drier at 70°C.

9. Resins.—Before the war the Germans imported large quantities of resins from the United States and France. To take the place of these imports, artificial resins were manufactured. Coumarone, for example, was made by treating at elevated temperatures the heavy hydrocarbons of the benzine series, boiling between 155 and 185°C. with concentrated sulphuric acid. The coumarone that is formed is polymerized and yields coumaron which is separated from the unchanged heavy benzines by distillation with steam. Bakelite and resinite, made by the condensation of phenol with formaldehyde, were also used.

10. Textiles.—The textile substitutes were of very great importance as all importation of cotton ceased and as the supplies of wool, hemp, flax and jute decreased very rapidly, threads and fabric were made from the nettle plant, which was cultivated very extensively. Processes for utilizing meadow grass are still being experimented with. An interesting substance called "solidonia," possessing a beautiful brilliant fiber, was made from the material formed between the bark and the wood of certain trees. This was mixed to good advantage with wool. Artificial wool made from wool waste was used in large quantities. The fiber called "stranfa" was a jute "ersatz," which was made from straw. This was used alone or mixed with jute and hemp to make cord, bags and fabrics for clothing.

The most interesting of the textile substitutes was thread made from paper. This was used alone or in combination with other fibers. Fabrics for all purposes were made from these fibers as well as twine, rope and transmission belts. Textilose was the name of a product of good quality, which consisted of paper covered with a thin coating of cotton. Textilite consisted of a mixture of paper fibers and various other textiles.

To make paper threads the layer of wet paper was cut while on the blanket of the paper-making machine or as it came out of the machine at the back end. In the latter case the strips were moistened first before twisting them into the form of a thread. The strength and resistive powers of the thread were enhanced by treatment with suitable chemicals. Threads were also manufactured, which consisted of a core of jute, hemp or cotton (or even a very fine metallic wire) clothed in paper.

SULPHUR

It is gratifying to note the change in the type of publicity which has accompanied the growth of the chemical industry. Manufacturers are putting more and more information into their booklets, many of which seek to convey real information, the interest of the manufacture being mentioned in an unobtrusive manner. A recent valuable booklet treats of sulphur in an unusually interesting way, laying stress upon methods of analysis, including the determination of moisture, ash, total sulphur, arsenic, selenium, and tellurium. Much of the sulphur now obtained in this country is produced with a purity of at least 99½ per cent. The moisture seldom exceeds 1/10 of 1 per cent unless the sulphur has been exposed to recent rains. With sulphur so pure the total sulphur is ordinarily determined by difference, that is, the possible impurities, ash and moisture, are determined, subtracted from 100 per cent and the remainder termed sulphur.

The booklet in question brings together, in addition to a short bibliography, a compilation of the physical and chemical properties of sulphur such as the atomic weight, the vapor density, the properties of commercial sulphur, forms of sulphur, its vapor pressure, surface tension, compressibility, coefficient of cubical expansion, coefficient of linear expansion, conductivity of heat, electrical conductivity, frictional electricity, melting point of both rhombic and monoclinic sulphur, a chart on the change of melting point with pressure, the transition temperature, specific heat, the triple point, heat of combustion, of vaporization and of fusion, change of viscosity of liquid sulphur, heat of solution in carbon bisulphide, and solubilities in various solvents.

The properties of commercial sulphur are given as follows: Insoluble in water and in most acids. Tensile strength approximately 200 pounds per square inch. Heat conductivity one-half that of cork and one-quarter that of ice. Electrical conductivity lower than that of any other solid substance. Melting point from 110.2 to 119.25°C., depending upon conditions. Boiling point 444.6°C. Ignition temperature 248°C.

The sulphur industry has developed rapidly with the advance of civilization, and today sulphur and the various chemicals derived from it constitute the most widely used chemicals in the world and millions of tons of the element are used annually. Prior to 1905 most of the sulphur was obtained from ores contlaining it, known as pyrites, or from mines in Sicily. By 1905 America had come into the world field with a production by novel methods devised by Frasch, a chemical engineer.

Oil Containers

Manufacture of Millions of Oil Barrels and Cans

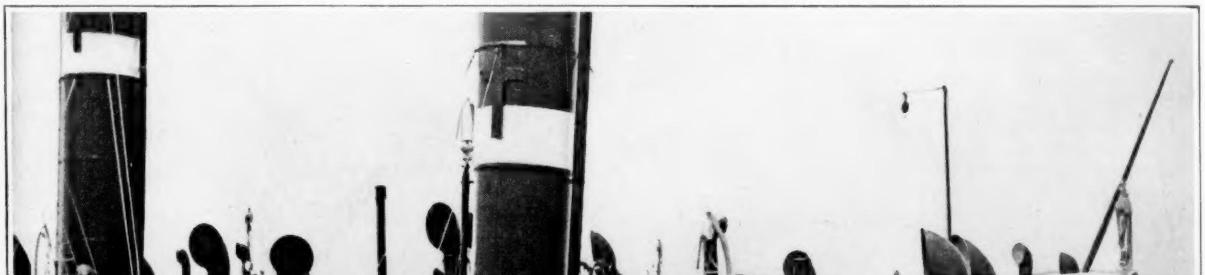
By Robert G. Skerrett

LAST year our oil wells yielded 376,000,000 barrels of petroleum, and during the same twelvemonth we imported 47,000,000 barrels of crude oil. The movement of this combined vast volume was achieved in the main by pipe lines, tank cars and ocean-going steamers especially designed for the transport of this raw commodity. But tremendous as this supply was the demand exceeded it. As a consequence, the urge for greater production remains, and this must be met if the world's needs are to be satisfied.

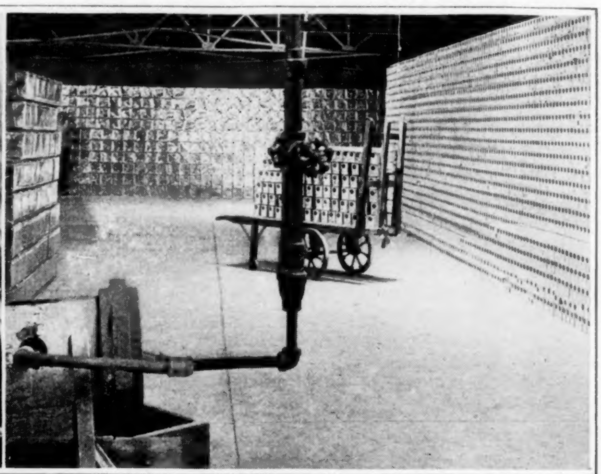
Dr. George Otis Smith, Director of the United States Geological Survey, recently announced that in the first three months of 1920 we were drawing from our subterranean stores of petroleum at the rate of quite 415,000,000 barrels a year and that the trend of consumption would represent total requirements of more than 490,000,000 barrels during the current twelvemonth! The foregoing figures have been cited merely to emphasize the immensity of the industry and to bring home to the public at large another angle of the problem—that of ultimately distributing the billions of gallons of derivatives which our many refineries turn out for various purposes.

As most of us know, it is from crude petroleum that we get gasoline, kerosene, lubricating oil, fuel oil, and a variety of other essential products which meet the different demands of our life of today and help to add measurably to the comfort, convenience, and indispensable activities of other peoples who have learned from us what these substances can do for them. Once the refiner has effected the extraction of these multiple derivatives from the crude oil of Nature's providing then it is necessary that suitable containers of one kind or another shall be fashioned in order that the marketable materials can be sent broadcast to their destinations. This means that barrels, cans, and boxes must be fabricated capable of holding securely the divers oleaginous merchandise.

Every big refinery, therefore, commonly maintains its own container department as a regular feature of its business organization. This is cheaper than buying from outside sources and, besides, saves time, inasmuch as the refiner can thus make sure that he has continually on hand the facilities for shipping his oil products. This branch of the industry may properly be dealt with in its two outstanding phases—one having to do with the making of barrel staves and headings and ready-to-assemble shooks for wooden cases and the other embracing the actual putting together of barrels and boxes, the fashioning of cans, and the filling and sealing of the several sorts of containers.



A TANK STEAMER BEING LOADED WITH OIL AT PORT ARTHUR, TEXAS



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STAMPING AND CUTTING MACHINES FOR MAKING OIL CANS

A STORE ROOM FILLED WITH FINISHED OIL CANS READY FOR FILLING

One of our biggest oil companies operates a cooperage subsidiary which furnishes the staves, headings and shooks and leaves it to the refineries, run by the same organization, to put these parts together. The cooperage enterprise starts work right out in the timberlands, and to meet its requirements it is obliged to cut over something like 60 acres of oak and 30 acres of pine and gumwood stands daily. The age of the gumwood trees ranges from 140 to 300 years, while the growth of the oak may cover a period of from 100 to 200 years. First-class lumber only will stand up under the stresses of transportation and handling; and inspection is, therefore, exacting.

The timber, after felling, is cut to log lengths and moved in the most expeditious manner to the mill where, if to be used for box shooks, they are sawed into boards of suitable thicknesses, but if intended for staves and headings, the oak is sawed into what is termed "bolt lengths," commonly 36 inches long for the staves and 22 inches long for the headings. The bolt lengths are next quartered longitudinally. The woodsmen are not permitted to fell trees of less than 10 inches in diameter at the butt. In working logs into staves, a machine known to the trade as a drum or stave saw is employed. This cuts the quarters and at the same time shapes the staves. To insure the desired strength, care is taken to saw both the staves and headings with the grain. These parts are piled in the open where they are left to dry for three months. Next, they are thoroughly kiln-dried, after which the materials are ready to be sent to a factory where the jointing and the circling of the headings are done.

The jointing of the staves consists of beveling the edges; and preliminary to rounding or circling the heading this part of the barrel-to-be also is nicely matched and jointed so as to insure close-fitting seams. No head is made up of more than five pieces; and these are held together by means of hickory dowels. Absolutely tight joints are obtained by inserts of heavy paper. With the heading thus assembled, *pro tem.*, a special machine, at one operation, does both the circling and the beveling of the circumferential edge so that the heading will fit snugly into the barrel.

Box shooks—the parts that go to form the tops, bottoms, sides and ends of cases—are made from pine, poplar and gumwood. These are manufactured as near the stands of timber as possible and then shipped in a knocked-down condition to the different refineries where they are nailed together ready for packing. This cooperage company employs something like 1,000 people and has houses, stationary and portable mills, machinery, locomotives, cars, steel rails, tugs, barges, and draft animals for carrying on its undertakings in the States of North Carolina, Kentucky, Tennessee, Mississippi, and Louisiana. It also operates in the States of West Virginia, Virginia, Alabama and Arkansas through outside interests working under contract. The company's timber holdings aggregate about 140,000 acres in fee simple, some of which has already been cut over, and there are 7,000 acres on which the timber only is owned. Four large plants and numerous smaller mills are engaged in the necessary activities of this particular organization. One of the big mills, which produces staves, headings and box shooks, consumes every working day a matter of quite 100,000 feet of logs. Now let us see what is done with these prepared wooden container units at the refinery.

In the port of New York there is located, within the limits of an immense refinery, the largest oil barrel factory in the world, which is able to produce every twenty-four hours 7,500 thoroughly finished hardwood barrels—the quartered oak in the staves and headings being quite on a par in quality with that used by furniture manufacturers. The staves and headings reach the plant in long train loads, and, as already explained, thoroughly seasoned. A careful check is kept of all of these parts and the tally of completed barrels must agree with the receipts of the incoming material—an allowance, of course, being made for a minimum of unavoidable waste due to sawing and trimming.

The assembling operations are delegated to men who have become extremely expert through long experience, and each performs his part with rapidity and precision. As a preliminary to the indispensable handwork, the staves are first put through planers and sawed to bring them to the exact dimensions desired. Next, the assemblers quickly stand the staves in a round forming frame, and then bind them for the time being at the top and bottom with light steel hoops. In this condition they are passed on to chambers where they are exposed to steam, from which they are withdrawn, when thus made more pliant, and sprung into their prescribed final shape. Following this, the barrels are dried by firing, and then cunningly devised machines square their ends and bore a bung hole in each. Ingenious apparatus press the the permanent steel hoops into position and, at the same time, displace the temporary binders. So far, so good, but a barrel for the oil industry must be more than commonly tight because of the searching, penetrating character of its contents.

Therefore, every barrel is subjected to a test with liquid glue fed in under air pressure. This forces the glue into the wood and through the tiniest hole or the slightest crevice. The procedure serves two purposes; it seals minute passages through which oil might escape and incidentally surfaces the inside of the barrel with a veneer that is impervious to oil. Should worm holes or other minor defects develop during the

glue test, wooden pegs are driven into these and the barrels are again submitted to a further pressure trial. When the barrels have passed this ordeal they are placed on tracks to drain, the surplus glue being caught as the barrels travel slowly toward an elevator. The latter lifts them to an air gallery where they are left long enough to dry out. When dry, they are painted and finally delivered to the filling rooms where they are charged with oil. Manual work is avoided wherever possible by the substitution of mechanical aids, and all these are the gradual outcome of years of experience.

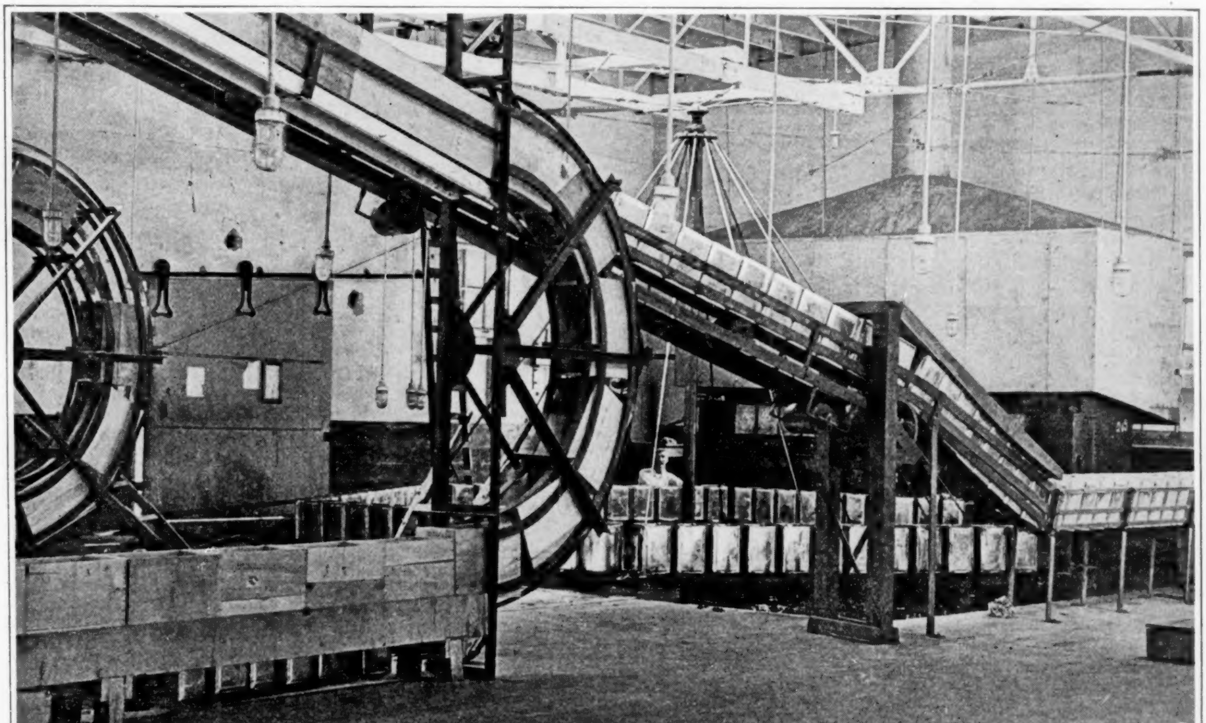
Here in the United States, most of the gasoline, kerosene, and petroleum lubricants start away from the refineries in tank cars which carry them to far-flung distributing stations established along the lines of our railways. Solid trains of tank cars go from the big refineries every day, but from these distributing points the contiguous district is supplied in various ways, and among these cans of different capacities figure conspicuously according to the nature of the trade. The manufacture of these cans both for domestic and foreign markets is one of the most interesting phases of the oil business, for numerous automatic agencies have been called into being to fabricate, to assemble, and to solder well-nigh the entire tin container.

Powerful stamping and cutting machines deal directly with the sheets of tin that are received at the plant. They press the metal and bend it accordingly as the material is fashioned into tops, bottoms and sides. The four sides are formed of only two pieces which are bent at right angles. The joints are made primarily by crimping the opposite vertical edges so that they will interlock and be fairly rigid when brought snugly together under pressure. In this state, the can-body is passed to a conveyor and held between narrow steel rails in such a way that one of the corners to be soldered projects downward and below the carrier.

As the conveyor moves onward, the pressed joint is trailed through an acid bath, which serves to cleanse the surface of the tin and to prepare it for soldering. Next, the acid-coated edge passes over brushes which wipe off the excess liquid, and then the corner is drawn through a trough filled with molten solder. This effects a perfect and binding union and makes the joint oil tight. Going a little farther, still on the conveyor, the can-body is turned axially through half a revolution, which brings the opposite corner undermost and in line for soldering. The steps just described are repeated. The can-body must now receive its top and bottom. These, previously stamped, are pressed in place, and the conveyor, always moving forward, tilts the can successively so that the four bottom and the four top edges may, one by one, be bathed in acid and then carried through the troughs of melted solder. The machines do in a single day an amount of soldering which would be achieved slowly and much more expensively if done by hand.

After the cans have been so fashioned they are subjected to the scrutiny of alert inspectors. If quite satisfactory they travel up an incline to the filler room and thence are routed to different departments, according to the nature of the product which is to be put into them. Let us suppose that the cans we are dealing with are of the 5-gallon kind so familiar to every automobilist. Each container is run beneath the filling apparatus and charged with exactly five gallons of kerosene, gasoline or naphtha for instance, and then moved to the testing floor and there allowed to stand for a prescribed period to determine if leaks develop. The need of this should be apparent, especially when we reflect how inflammable the product is and how apt it would be to occasion injury to other commodities with which it might be associated in transit.

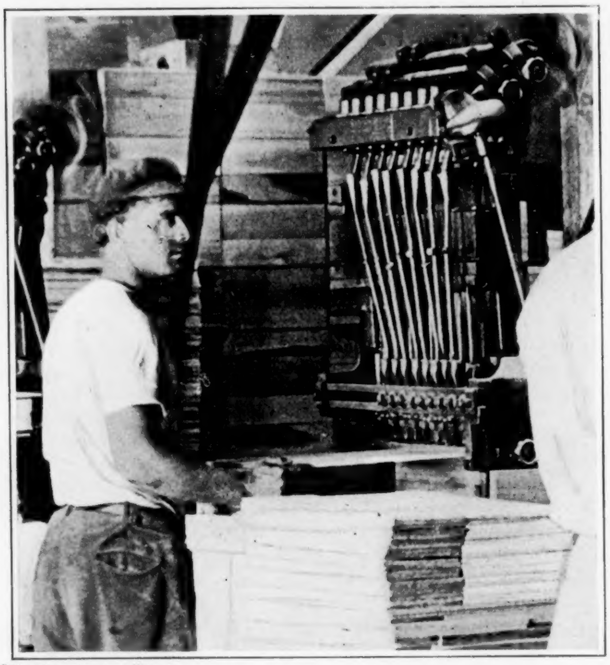
The opening in the top of the filled can is closed by hand soldering. To facilitate this work, there is in some plants a big circular table holding along its outer edge 50 charged containers, and around this are placed a number of experts who rapidly seal each can as the slowly-turning table brings one after the other within reach of their soldering irons. Despite the fact that this procedure seems to partake of the perilous the fact remains that explosions or conflagrations are rather infrequent. And now the filled cans are moved onward to the packing rooms where two 5-gallon cans are placed in each



BOX CONVEYORS IN THE FILLING ROOM AT PORT ARTHUR, TEXAS

wooden case preparatory to shipment. It is in the form of case oil, especially, that so much of our gasoline, kerosene and naphtha is sent abroad.

These cases are made from the shooks which come direct from the lumber mills, and the assembling into box form is accomplished quickly by means of nailing machines. All the operatives have to do is to feed in the shooks and the machines force the nails into place, a whole side at a time. The four sides are put together first and then follows the bottom. The ends and sides of the cases travel through machines which print upon them the name of the company and the character of the contents. As far as practicable, the descriptive marking is in the language of the country to which the box is destined. After the cases are packed, another set of automatic nailing machines secure the covers; and from that point the goods are conveyed several hundred feet down to piers where they are available for loading upon lighters or



MACHINE FOR NAILING BOXES IN WHICH OIL IN CANS IS SHIPPED

aboard deep-sea craft. It is at this stage of the work that the boxes are first handled by men who lift them from the mechanical carriers to stack them on the deck of a barge or to swing them into the hold of a near-by steamship.

Until recently it was possible to get plenty of yellow pine for the fabrication of cases, but now, owing to a scarcity of this lumber, it is necessary to substitute gumwood. This presents a more difficult problem for the nailing machines. However, they are standing up to their tasks very well. The plant in question produces 50,000 wooden cases and 100,000 five-gallon tin cans every day for the export trade. It is necessary to do this because of the continuous demand for containers, and also because it would be difficult to provide storage room for a reserve sufficient to last more than a day or two. In short, the containers are made as fast as possible to meet the requirements of each twenty-four hours.

Until lately the wooden barrel had things all its own way in the oil industry, but the steel barrel is rapidly coming into use owing to its ruggedness and ability to withstand a great deal of rough treatment without suffering materially. In the end, they are really cheaper than their oaken rivals. When running to capacity, the New York plant of the refinery produces daily 500 of these containers, and each has the name of the owner and the net capacity stamped upon it. These barrels are galvanized inside and out. By means of immense machines, flat sheets of steel are speedily shaped into bilge barrels. They are then plunged into a naphtha bath to cleanse their surfaces, after which they are immersed in tanks containing molten zinc. The same department also repairs thousands of metal barrels of various types, and this is an important part of the work. For export purposes the company likewise makes a large number of light iron straight-sided drums, which do not return to the filling stations. These containers are of different sizes to suit the local trade of the several parts of the world to which they carry petroleum products.

In South America, China and the Far East generally, and in Africa, the 5-gallon cans are indispensable because commodities have to be transported so largely upon the backs of pack animals. In this way the wooden cases and the tin containers find their way into outlying districts where the natives promptly put the boxes and the cans to varied uses after their contents have been removed. From the boxes they make pieces of furniture; and the empty cans are employed for carrying drinking water, for the collection of rubber in the tropical forests, and the shining tin is also worked into a variety of domestic articles prized by the housewife. Lined with cement, the large cans are easily converted into efficient charcoal stoves. In short, the wooden boxes and the tins fit into the economic life of these far-off foreigners and are effective mediums in stimulating the purchase of the petroleum products. They are premiums which promote trade.

ACACIA BARK AS AN INDUSTRIAL MATERIAL

DURING a former period, the continent of Europe furnished a considerable supply of tanning substances, bark, and the like, to Great Britain, but when the conditions of the war put a stop to this traffic, the British market had recourse to a large extent to the acacia bark or "wattle bark," which prevails in the South African region. Extracts from this bark began to be manufactured not only at home but also in South Africa itself, and moreover, recent figures show that 6,609 (metric) tons of bark were exported from Natal to Russia by direct transit. The present bark comes from several species of acacia which are indigenous to Australia and were introduced into east and south Africa where they are cultivated in plantations. The tanning material from this source which is best known in Europe is the "black wattle." Production of acacia bark now has a great importance in South Africa and especially in Natal, where rapid progress is being made. In 1916 the area covered by acacia cultivation in Natal was upwards of 130,000 acres. Exports of cut acacia bark from South Africa figured at 51,683 tons at an average price of $50 per ton. The bark is furnished especially by the large-leaved or golden acacia and the black acacia. Commercial bark contains an average of 32 per cent of tannin, while the extract contains 60 to 65 per cent. After the operation of tanning or of preparing the extract, the residual bark can still be utilized for paper manufacture, and experiments showed that such bark, which contains 11.5 per cent water and 41.2 per cent cellulose, will give from 28 to 35 per cent (according to the treatment) of a dry paste, which, however, cannot be bleached. Large scale experiments in the factory were carried on, and it was found that from 28 to 30 per cent of a paper paste can be produced which is excellent for the manufacture of heavy packing board of dark color. Acacia wood can also be used for paper, and it yields 61 per cent of cellulose with reference to the dry wood, affording a high percentage of paper paste, or 46 to 50 per cent. But as the fibers are of a short nature, such paper is not found to be sufficiently durable, but the paste can be employed to advantage in making up straw board, especially if mixed in equal parts with another material having longer fibers such as the residual acacia bark already mentioned.

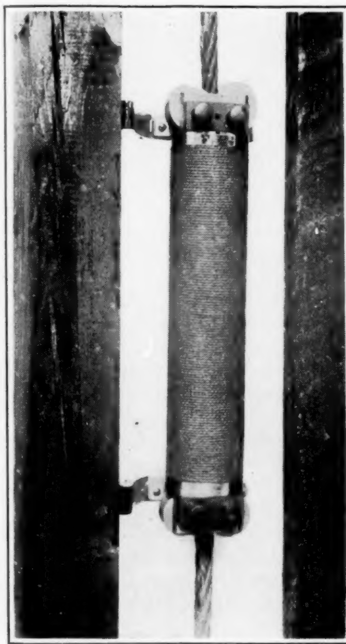


FIG. 1. ELEVATOR CABLE DEFECTOSCOPE

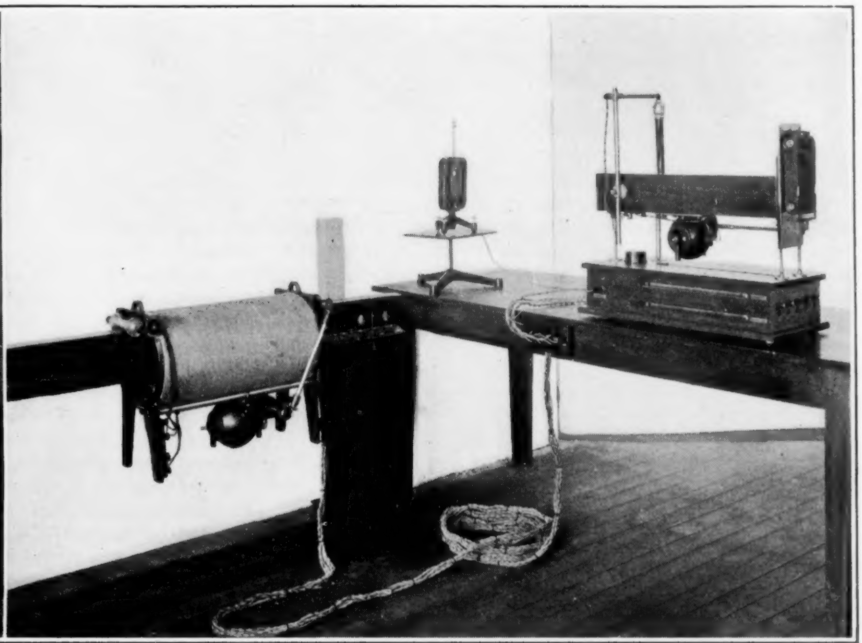


FIG. 2. EXPLORING A RAIL FOR DEFECTS WITH AN APPARATUS THAT MAKES A RECORD OF MAGNETIC VARIATIONS

Magnetic Analysis of Steel

A New Method of Locating Defects without Subjecting the Piece to a Destructive Test

By Charles W. Burrows, Ph.D.

DO you remember the story of Damocles and the naked sword suspended over his head by a single hair?

If Damocles could be brought to life and made to realize the imminence of danger in modern life, his fears would be multiplied a thousand fold. He would realize that the failure of any one of a hundred parts of his touring car speeding along the boulevard would land him in eternity. A broken elevator cable and the failure of the safety catch and all would be over. The safety of his train ride depends upon the reliability of countless details. Any one of the five rails passed over every second as his train speeds along at the rate of sixty miles an hour is potentially as threatening as his one-time feebly suspended sword.

Just as the hair that held up the sword of Damocles was equal to its task, so the component parts of our complicated modern machinery are able to meet the demands made upon them. This security is attained by suitable testing. The mechanical engineer with his tensile testing machine, the chemist with his reagents, the metallographist with his microscope are all doing their parts in securing reliable and adequate material. In addition to the established methods of test, physicists are ever on the lookout for some new means of examination which will add greater safety. One of the most recent means of examination is magnetic analysis.

It has long been known that the magnetic properties of steel depend upon the chemical composition and heat treatment, and that the mechanical properties have a similar dependence. For the last eight years the author of this paper has been trying to ferret out the exact relations that exist between the magnetic and other properties of steel.

Every steel has its own peculiar magnetic and mechanical properties. Variations in chemical constitution bring about corresponding variations in magnetic and mechanical properties. Heating a steel and quenching it in cold water hardens it. Here too there are corresponding magnetic changes. In short there are no two pieces of steel with differences however slight that do not show corresponding magnetic differences.

The entire story of the steel is recorded within the steel itself. It is written in magnetic language and may be read by anyone who takes the trouble to decipher the records. The magnetic analyst is able to tell whether a steel contains much or little carbon, whether it has been quenched or annealed, whether it is sound of structure or full of invisible blowholes. The magnetic test differs from all other methods of test in that it does not destroy or even mar the material. Suppose for example that a steel airplane guy wire is to be tested. The mechanical engineer puts it in his tensile machine and pulls it in two, and says, "Yes, that was good wire. It required five times the service load to break it." The usefulness of the wire however is destroyed by the test. The chemist would have dissolved the wire and from his analysis could tell whether it contained the proper constituents. He could not tell whether it had received the proper heat treatment. The metallurgist with his microscope would tell you that the small piece which he polished up for his specimen showed the proper structure and if the wire was of uniform material throughout it would be satisfactory. These tests either destroy the test specimen or deal with only a small portion of it. To be of service, test specimens must be prepared which are not identical with the material to be put in service. Assumption is made that the test and service materials are similar. This vicarious testing while it is very helpful leaves much to be desired. On the other hand the magnetic analyst does not destroy the test material and can therefore examine the very material that is to enter into a given structure.

Magnetic analysis may be of assistance in many different ways. First in the detection of flaws in material which should be of the highest degree of uniformity, such as airplane stays, rails, gun forgings, etc. Second, the determination of quality. Under this head comes the determination of the perfection of a

welded joint or the repair of a steel or cast-iron casting. Frequently as in the case of welded boiler tubes there is no other means of examination, especially when the desired quality is secured by a given heat treatment. This is applicable to cutlery, small tools, axles, ball bearings, etc. Third, the determination of the life of material in service. For instance, an automatic recording device can be placed near a mine or elevator cable, which will give a continuous record of the condition of the cable and give ample notice of any weakening or dangerous wear of the cable. Fourth, in the study of the design of high grade machinery such as automobiles, typewriters, machine guns. The procedure here is to make magnetic tests of the component parts during the course of a life service test. As soon as any element begins to show signs of overstrain or fatigue warning is given in terms of certain changes in the magnetic properties.

For the purpose of determining the variation of magnetic homogeneities along the length of a specimen the writer has invented an instrument known as the "magnetic defectoscope." Of the various magnetic characteristics that might be used this instrument employs the apparent permeability of the

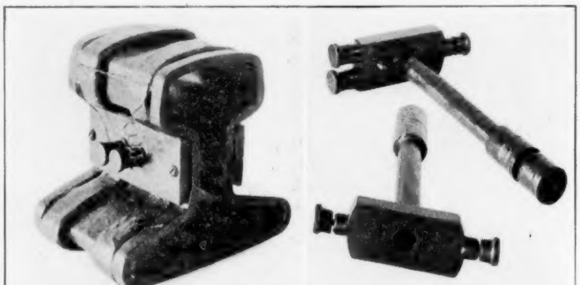


FIG. 3. DETECTOR TEST COILS FOR THE EXAMINATION OF RAILS (LEFT) AND WIRES (RIGHT)

specimen under a moderately high magnetizing force. The apparent permeability which for our purpose we may consider as substantially equivalent to the actual permeability is chosen because it is not only a good criterion of the magnetic nature of the steel but also of the quantity which lends itself to ready measurement, because under this condition the steel is practically uninfluenced by its previous magnetic history.

We may recognize six elements in the magnetic defectoscope. First the bar must be magnetized. In the general type of apparatus the magnetization is effected by a relatively short solenoid energized by a direct current of such value that the magnetization of the specimen is carried well beyond the knee of the induction curve. The second element is the means for detecting magnetic variations in the bar. This detector consists of two test coils having the same number of turns and surrounding the specimen. The magnetizing solenoid and the detector are rigidly connected together and are given a relative motion along the length of the specimen by means of a suitable motor which forms the third element of the system. As the detector occupies different positions along the length of the test material, it is threaded by an induction which depends upon the nature of the specimen. If the specimen is not quite uniform the magnetic induction threading one to the coils and the detector is different from the magnetic induction threading the other coil, with the result that the electromotive force generated in one of the test coils is different from that generated in the second test coil. Consequently the small differential electromotive force is impressed upon the detector system every time it passes over the magnetic inhomogeneity. The double test-coil is used in order to eliminate the effect of any electromotive force which might be induced by variations in the magnetizing force. We are thus able to use as our source of magnetizing current the ordinary commercial direct-current power circuit. The fourth element is an indicator which must be responsive to the small electromotive force developed in the detector coils. For this purpose we find it convenient to use a heavily dampened D'Arsonval galvanometer of short period. The indication given by the galvanometer is recorded by the fifth element of the equipment. The record is essentially a photographic film caused to move uniformly across a small slit through whose opening a spot of light is reflected by the galvanometer. The sixth and last element is the control box which contains all the necessary electrical switches, rheostats and instruments.

APPARATUS FOR TESTING RAILS

In the rail defectoscope the magnetizing solenoid, the detector test coils and the electric motor for driving the equipment over the rail are mounted in one unit, as shown in Fig. 2. The magnetizing solenoid is wound with well insulated copper wire on a brass tube approximately 10 inches in diameter and 20 inches long. The carriage itself travels on two rollers, one of which is driven through bevel gears by means of a small electric motor attached to the supporting frame of the solenoid. Actuated by the second roller through a pair of gears is a pair of electrical contacts which are closed momentarily when the carriage has traveled a distance of three feet. Of the two pair of binding posts, mounted on one leg of the carriage, one connects to the magnetizing solenoid and the other pair to the detector coils. The detector coils which are not visible in this illustration are shown in Fig. 3.

The camera proper is mounted in a slide opposite a horizontal slit in an elongated dark box. The camera is caused to move across the slit by means of suitable gearing connected to an electric motor mounted on the underside of the dark box. The control box is shown beneath the camera box. On the sides of this box are mounted the necessary switches and rheostats for the operation of the apparatus. The ammeter for indicating the current in the magnetizing solenoid and the electric lamp used with the reflecting galvanometer are also shown mounted integral with the apparatus. On the sides of this box are mounted the necessary switches and rheostats for the operation of the apparatus. The ammeter for indicating the current in the magnetizing solenoid and the electric lamp used with the reflecting galvanometer are also shown mounted integral with the apparatus.

The test rail forms part of a closed magnetic circuit by resting at its extremities upon two eye beams connected by an auxiliary rail at the bottom. The camera is shown pointing at the galvanometer. The camera is raised to its upper position in which the light reflected from the concave mirror of the galvanometer is focused upon the ground glass attached to the bottom of the camera case. In the foreground is seen the cable connecting the carriage to the control box.

With the apparatus set up as shown in Fig. 2, all that is necessary in order to secure a record of the magnetic homogeneity of the rail is to operate the appropriate switch and thirty seconds later to develop the photographic film.

THE ROD DEFECTOSCOPE

The essential elements of the rod defectoscope are the same as those used in the examination of the rail. Because of a smaller size of the material to be tested, it is more convenient to cause the rod to pass through a stationary solenoid rather than to hold the rod stationary and move the solenoid as we have done in the rail defectoscope. The galvanometer recording equipment and control box is substantially the same as that employed in the examination of steel rails. If a permanent record is not desired the photographic part of the equipment may be replaced by a translucent scale or a telescope and scale.

Fig. 4 shows the solenoid of the rod defectoscope with the driving mechanism, mounted on a single base.

The magnetic examination of wire is carried out by means of equipment quite similar to that for rods. In many cases the apparatus may be placed so as to test the wire during its

process of manufacture, thus utilizing the commercial method of causing the wire to move from one stage of manufacture to another.

MAGNETIC INSPECTION OF ELEVATOR CABLES

The magnetic examination of cables is quite similar to that for wires. Fig. 1 shows a cable defectoscope attached to a frame work with the cable under test passing through it. Records are made photographically as in the case of rails. A multiple cable defectoscope for the examination of the several cables of an elevator is under development. The recording part of this proposed apparatus will be placed where it can be readily operated by the engineer in charge or by the inspector. With this apparatus each cable of each elevator can be examined every day and a photographic record of its condition may be made. Ordinarily defects of service wear and tear will appear gradually. When the elevator cable is new the record will appear as a straight line. When a break in a single wire develops the record will show a sharp notch in the original straight line. As other wires break or strains result from extra tension in the wires caused by the original broken wire or wires, the irregularity in the record becomes more conspicuous. Thus there will be an infallible indication when the cable is deteriorating and needs careful visual inspection or possible removal. After the engineer in charge becomes familiar with the irregularities of the record and the corresponding defects in the cable he will readily be able to estimate from a visual inspection of the photographic record how near the cable is to a dangerous condition.

The following news item was clipped from the New York *Tribune* of September 4th:

"An inquiry into the cause of the elevator accident in the Clarendon Building, Eighteenth Street and Fourth Avenue, last Tuesday came to an end yesterday after Assistant District Attorney Marro questioned three witnesses. *The accident resulted in the death of three persons and the injury of fourteen.* Those questioned were P. F. Foley and Charles Dreier, building inspectors of the Aetna Insurance Company.

"Foley and Dreier inspected the elevator on April 4th and *found it to be in good condition.* Both inspectors examined a piece of cable taken from the wrecked elevator and reported a *defect on the inside* of the cable which is not noticeable on the outside."

Here is a case of a fatal elevator accident in spite of the fact that careful inspections had been made. The final cause of the accident was due to defects in the material which would escape purely visual examination. Is it presumptuous to hazard the opinion that this disastrous accident with its resulting loss of precious human life would not have occurred if this elevator system had been guarded by the magnetic cable defectoscope which would have given ample warning to the superintendent of the building that the cables were approaching a dangerous condition?

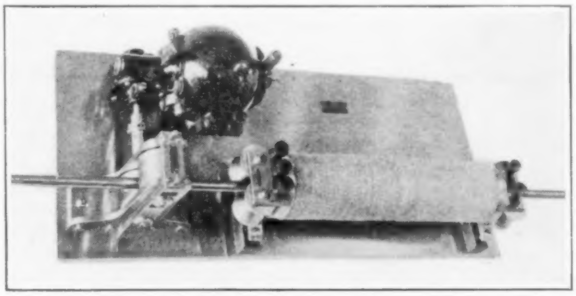


FIG. 4. ROD TESTING SOLENOID AND DRIVING MECHANISM

Fig. 5 shows how sensitive the instrument is to the slightest variations in the homogeneity of a specimen. The upper photograph is the record of a commercially perfect bar of tool steel. The straight line is characteristic of perfect material. The lower photograph is the record of the same piece of steel after it has been strained beyond the elastic limit at the point indicated by the hump in the photographic record. The bar had been subjected to repeated bends in opposite directions until it became so weakened that although there was no visible defect in the specimen, it showed traces of rupture just as the repetition of the same mechanical treatment was completed. In other words this is the record of a piece of steel which has lived half of its useful life. If similar records of an elevator cable were to be taken daily we should have a family of records in which the hump grows gradually from nothing to the sharp peak just before rupture. The evidences of decreasing strength in the steel would be just as unerring as the growing evidences of weakness in man as old age approaches.

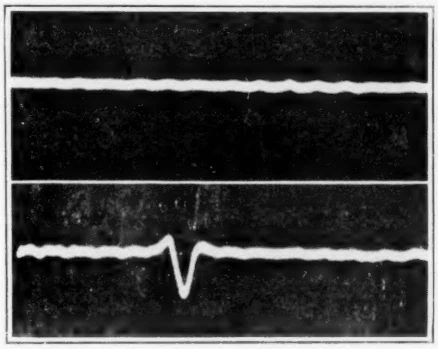


FIG. 5. RECORDS OF A PERFECT BAR (ABOVE) AND SAME ROD AFTER BEING STRAINED BEYOND ELASTIC LIMIT (BELOW)

EXAMINATION OF STRIP MATERIAL

The magnetic defectoscope lends itself quite readily to the examination of strip material. Material of this shape is widely used in the manufacture of band saws, hack saws, and coil springs.

Mechanical inequalities in band steel which is used in the manufacture of phonograph motors is largely responsible for certain defects in phonographic performance. The magnetic examination of such material would enable the manufacturer of spring motors to build motors of uniform performance and to guarantee the performance of each individual motor.

TESTING OBJECTS OF CIRCULAR SYMMETRY

The test methods so far mentioned have been confined entirely to the examination of rectilinear material. The same fundamental principles may be applied to the examination of material which possesses circular symmetry. Work has been done on large disk-shaped forgings by applying successively to the various parts of the disk a given magnetomotive force and noting by means of suitable detector coils any variations in magnetic homogeneities which may occur. Investigations along this line have been in progress for some time and the results thus far obtained are sufficient to insure the commercial success of this test method.

Objects of circular symmetry which are small in size do not lend themselves readily to the method of examination just described. Small circular objects are best examined magnetically by placing them in a rotating magnetic field and measuring by the same suitable device the magnetic torque exerted on the specimen by the rotating magnetic field. In this case the quantity measured is not the permeability. It is rather a combination of residual induction and coercive force. Roughly it is proportional to the product of these two quantities and substantially equivalent to the magnetic hysteresis of the material.

UNDEVELOPED FIELD OF MAGNETIC ANALYSIS

In addition to the work which has already been done on rails, wires, rods, and cables and upon specimens having circular symmetry such as ball races, balls and milling cutters,

there is great opportunity for additional development along these lines. Tires, gear rings, roller bearings, disk blanks and circular saws, are important steel products whose magnetic examination gives great promise. Specimens such as drills, reamers, taps and other small tools have received but little investigation and yet are of sufficient importance to warrant our consideration. Small irregular shapes such as cutlery, gravers' tools, small machine tools and chain links, need investigation. Large irregular shapes may present difficulty, but in many cases there is sufficient promise of success to justify investigation. At the present time there is no satisfactory method for the examination of crank shafts, steel bottles, band saws and a great variety of miscellaneous shapes. Other problems for which the magnetic test may yield a satisfactory solution are the degree of malleabilization, the depth, case hardening, the degree of perfection of welded joints and study of strains induced in the various elements by the repeated stresses of the service tests.

Locating Leaks in Water Mains*

Detecting a Leak by Sound, Colored Solutions, Water Hammer, and Hydraulic Gradient

Some of the methods employed in locating leaks in underground pipes were described at the recent meeting of the Illinois section of the American Water Works Association by Prof. H. E. Babbit, University of Illinois. A leak discovered by a surface indication is likely to be at some distance from that point and may be located by driving a rod at intervals back from the wet spot.

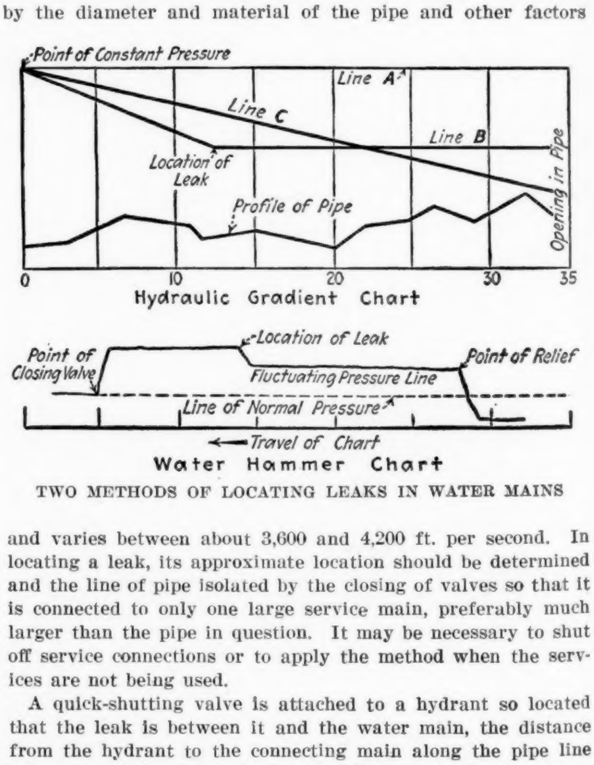
Sound Detectors.—Leaks which give no surface indication are the most common and the use of sound is the principal method of detecting and locating them. Water escaping at high velocity through a small aperture will make more noise than when the aperture is large, while a free discharge will be more noisy than a submerged discharge. One of the simplest instruments used for locating leaks by sound is the aquaphone, which consists of a metal rod soldered to the center of a thin metal diaphragm as used in an ordinary telephone receiver. The point of the rod protrudes from the end of the receiver and is placed in contact with the pipe or fixture. If the pipe is buried, a rod may be driven down to make contact with it, the instrument being placed in contact with the rod. Considerable experience is necessary for the successful use of this instrument.

The detectaphone, the sonograph, the sonoscope, the geophone, etc., are somewhat similar instruments, the volume of sound in some of these being increased by an electrical amplifier placed in the line between the point of contact and the receiver. The receiver is similar to the ordinary telephone instrument with electric coil and magnet. The sound waves set up in the pipe are converted to electric waves in the amplifier and transmitted to the receiver much more loudly and clearly. All of these instruments require direct contact with the pipe, which is an undesirable feature, as the exact location of the leak may require excavations to be made, since the sounding rod is not always satisfactory.

In the Darley leak locator, direct contact with the pipe is not required. A delicate sound detector is set up on a small four-legged brass table which rests on the surface of the ground and is protected from air currents by placing the box containing the electric cells over it when in use. The vibrations set up in the detector are converted to electric waves which are transmitted to a specially sensitive telephone receiver. This instrument is so sensitive that it will detect the sound of a leak through the pavement and ground at the ordinary depths to which water pipes are buried, but it cannot be used in a high wind or where other noises may interfere.

Hydraulic Gradient.—The characteristics of the hydraulic gradient are useful in the location of a leak, as shown in the diagram, the profile being that of a long pipe line or an isolated portion of a distribution system. It is suspected that a leak exists somewhere between stations 0 and 35. If the pipe line is shut off completely except at 0 and no leak exists, the gradient will lie along the line *A* and the pressures throughout the pipe line will indicate this height. If the pipe is opened and no leak exists the hydraulic gradient will be represented by line *C*, provided the diameter and other conditions are constant. If a leak exists and the pipe is closed the pressure at station 35 will be less than that at 0; the line of pressure will be horizontal up to the leak and will slope uniformly upwards from there to station 0, as in line *B*. These lines can be determined by locating two or more points and plotting their position on the chart, the leak being located at their intersection. This method was used with success by Professor Babbit in locating a leak in a five-mile pipe line at Nogent-en-Bassingny, France, during the war.

Water Hammer.—The phenomenon of water hammer may be utilized. If a valve in a pipe line is closed quickly, a wave of high pressure travels from the closed valve up to the pipe to a point of relief and a wave of low pressure then returns to the original starting point. The pressure at the valve fluctuates above and below normal until the disturbance has become stilled. Intermediate discharges between the valve and the point of relief will cause fluctuations in the pressure at the valve. The speed at which the wave travels is affected by the diameter and material of the pipe and other factors



TWO METHODS OF LOCATING LEAKS IN WATER MAINS

and varies between about 3,600 and 4,200 ft. per second. In locating a leak, its approximate location should be determined and the line of pipe isolated by the closing of valves so that it is connected to only one large service main, preferably much larger than the pipe in question. It may be necessary to shut off service connections or to apply the method when the services are not being used.

A quick-shutting valve is attached to a hydrant so located that the leak is between it and the water main, the distance from the hydrant to the connecting main along the pipe line being accurately determined. A delicate recording pressure gage is attached to another nozzle on the hydrant. In the pulsograph, a dial is revolved by clockwork, time is recorded by the vibrations of a tuning fork and variations in pressure are recorded by a delicate pressure gage. After the instruments are connected and the clock work is running, the valve is opened and is then suddenly closed while water is flowing, when the pressure line on the diagram will jump up and re-

*From *Engineering News-Record*, May 27, 1920, pp. 1061-1066.

main until a slightly relieving wave has returned from the point of the leak when it will drop a little. The pressure will then remain constant until the low pressure wave has returned from the point of relief. The exact location of the leak is then determined by proportion from the diagram.

Chemicals.—A method requiring the use of chemicals was suggested by T. J. Hoxie in the *Journal* of the New England Water Works Association, Vol. 27, p. 307. The leak is located within a certain section of pipe which is isolated and all service connections are closed. A corporation cock is tapped into the main above the leak, to which is connected a 6- or 8-inch length of 2- or 3-inch pipe and a valve. Two or three pounds of caustic soda are inserted in the tube, the large valve is closed and the time of opening the corporation cock is recorded. Samples are collected at various points along the pipe and tested for alkalinity. As soon as alkalinity is found at any point it indicates that the leak is below that point because the flow created by the leak has carried the chemical down. Finally a point will be reached where the alkalinity does not appear. The indication is that the leak is between this point and the point at which it was last found. Water is withdrawn from the point at which the alkalinity has not appeared, the quantity drawn before alkalinity being carefully measured. This quantity divided by the volume per unit length of pipe will determine the distance to the leak.

Piston or Displacement.—An ingenious method based on volumetric displacement was used for the location of a leak in a pipe line during the construction of the Field Museum in Chicago. A piston was made which fitted the inside of the pipe closely. A Y-branch was inserted in the pipe line, the piston was put in the pipe and a cable attached to it was passed through a packed joint in the plug closing the Y-branch. The water was then turned on to the pipe just sufficiently to keep the piston moving. When it had reached the leak it stopped, and the length of cable paid out measured the distance to the leak.

Leaks in Submerged Pipe.—For locating a leak in a submerged pipe a quantity of bluing was dumped into the line and the appearance of color at the surface located the leak.

Wireless Pipe Locator.—If the location of the pipe line itself is unknown it may be found by a wireless pipe locator. A circuit is made by connecting two points on the pipe line by an electric wire. A battery and vibrator are put in this circuit, the vibrator serving to interrupt current rapidly. An induction coil and a detecting coil connected to a telephone receiver are carried in the hand. When the induction coil held in a horizontal position is brought into the vibrating electric fields set up by the electric circuit through the pipe and wire a singing noise is heard in the telephone receiver. The volume of sound increases until directly over the pipe, when it ceases altogether. If the coil is then turned into a vertical position the loudest sound is heard.

THE WIRELESS TELEPHONE AND FUNDAMENTAL RESEARCH

IN its effort to further scientific and industrial research, the National Research Council frequently meets those who are willing to support research which gives promise of early financial return, but who are not very sympathetic to so-called pure science, meaning research undertaken with a primary object of establishing a truth. In order to emphasize the necessity for supporting such fundamental work if we are to establish scientific laws applicable to the solution of industrial problems, an exhibit of the wireless telephone has been arranged under the auspices of the Council by the American Telephone and Telegraph Company, the Western Electric Company, together with the co-operation of the United States Signal Corps and air service. This exhibit has been in Washington for some weeks, is now installed in the American Museum of Natural History in New York and may later be shown elsewhere.

There is a series of working models, ten in number, which demonstrate the principles established by various investigators, most of whom have worked in the realm of pure science, and the way in which the wireless telephone as we now know it is based upon this work becomes quite apparent. Going back a hundred years, the exhibit begins with Oersted's classical experiment performed in 1820 to prove that there is a relation between electricity and magnetism, and that a wire through which an electric current is flowing is surrounded by a magnetic field. Then follows a reproduction of the experiment by which Faraday and Henry separately and almost simultaneously demonstrated a second relation between electricity and nagnetism, showing how an induction current may be produced with an electro-magnet. The next in the series is Faraday's experiment showing how the plane of polarized light is rotated in a magnetic field, the various component parts of white light being rotated by different amounts. The oscillating character of the spark is the next point emphasized, the revolving mirror being employed to draw out the image of the spark so that the oscillations may be seen.

The detection of Hertzian waves using a copper loop, between the ends of which a vacuum bulb containing a fluorescent material encloses the spark gap, proves of real interest to the layman and scientist alike and gives him a clearer impression of the magnitude of the problem which has been solved. From this point on, the exhibit deals with cathode rays and the development of the vacuum tube, "audion," upon which the successful operation of the wireless depends. The next few experiments indicate how electrons flow from a hot filament in a vacuum and how this phenomenon is employed in the "audion" to produce a valve for the control of large quantities of energy by the use of relatively small quantities and also to obtain sustained oscillations. The valve action of the "audion" is clearly demonstrated by an amplifier so arranged as to cause a lamp to light or a spark to pass between electrodes when one speaks into a transmitter.

The story ends with a set of wireless telephones, which are used by those visiting the exhibit, and moving line drawings which present diagrammatically the principles which the apparatus demonstrates. The employment of motion pictures of this type enables the uninitiated to get a remarkably clear conception of what takes place and undoubtedly provides us with one of the most valuable methods of teaching that could be imagined.

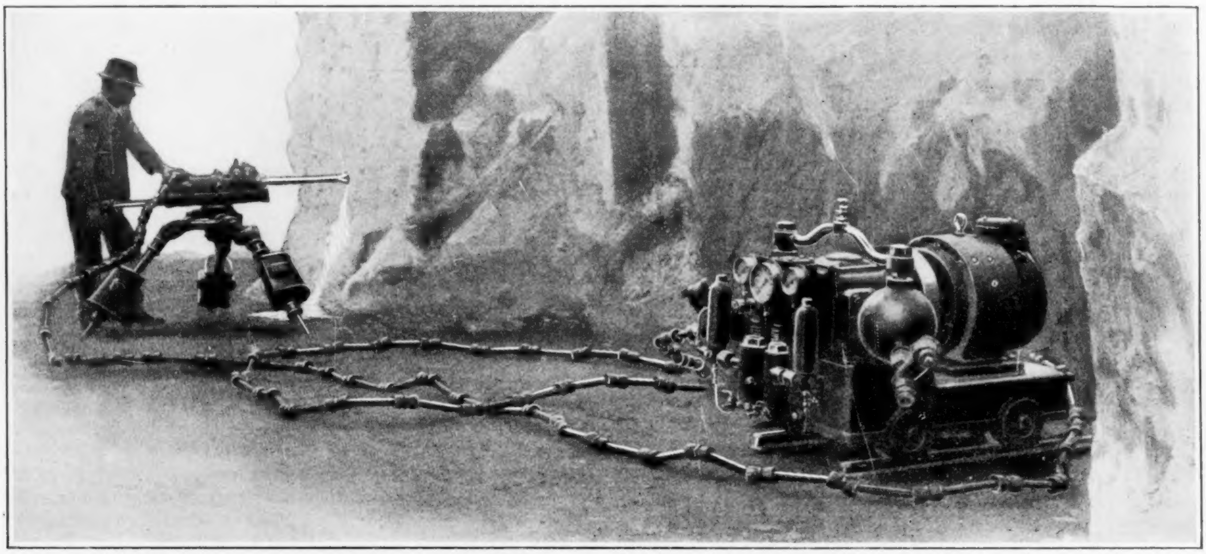
The exhibit has attracted a great deal of attention thus far and without question accomplishes its purpose, since it becomes evident to the most casual observer that the wireless telephone, which must be looked upon as a facility added to our present methods of communication for special uses, but in no way displacing the older telephone, would have been impossible but for the work done in the realm of pure science.

COMPARATIVE TRIALS OF STILL AND SULZER ENGINES

DURING the war Messrs. William Denny and Brothers fitted an experimental twin screw 250 i.hp. "Still" engine in a shallow draft vessel originally destined for experimental manufacture and installation of Sulzer engines.

The vessel thus engined was exhaustively tried, and, on the conclusion of the war, the Still engines were removed, a set of Sulzer engines originally intended for it installed and similar trials conducted.

The trials showed the maneuvering of both types of engine to be quite satisfactory. From ahead to astern the time was about 5 seconds, and in this respect the Still engine showed a slight advantage. During the trials the Still engine worked entirely under the waste heat conditions, *i.e.*, no oil was burned in the boiler. The principal aim of the trials was to ascertain accurately the oil used in terms of the speed of the vessel.—Abstracted by *The Technical Review* from a paper by William Denny read before the Institution of Naval Architects, July 7, 1920.



A ROCK DRILL OPERATED BY WAVE TRANSMISSION OF ENERGY FROM THE GENERATOR SHOWN AT THE RIGHT

Wave Transmission of Power

A New Hydraulic Power System Analogous to Alternating Current Electric Power

ONE of the important contributions to military aeronautics during the war was a means of synchronizing the operation of a machine gun with the revolutions of an airplane propeller so that it was possible to fire between the blades of the propeller without danger of hitting them. Several different types of synchronizers were developed and a most successful one of these was a mechanism invented by Mr. George Constantinesco, a Roumanian engineer, in which complicated systems of levers and gearing were avoided by the use of "wave transmission" through a liquid column in a watertight pipe of small bore. A description of this invention appeared in the SCIENTIFIC AMERICAN of May 17, 1919, p. 512, and a brief explanation of the "sonic wave" system of power transmission was published in the SCIENTIFIC AMERICAN MONTHLY of June, 1920, page 567.

The British manufacturers of the "C. C. Gun Gear," as the synchronizing mechanism was called, realized that Constantinesco's system provided a new form of transmission capable of adaptation to a large variety of operations and proceeded to develop it extensively. A brochure which has just been issued shows machinery for generating sonic waves, flexible tubing for transmitting them and rock drills, riveting hammers, riveting machines, coal cutting machines, pile driver equipment, etc., operated by the new hydraulic transmission. The accompanying illustrations have been reproduced from this brochure to which we are indebted also for the following brief description of sonic wave transmission:

There are at present five methods in commercial use for the transmission of power, namely, steam, direct mechanical, electric, compressed air, and hydraulic.

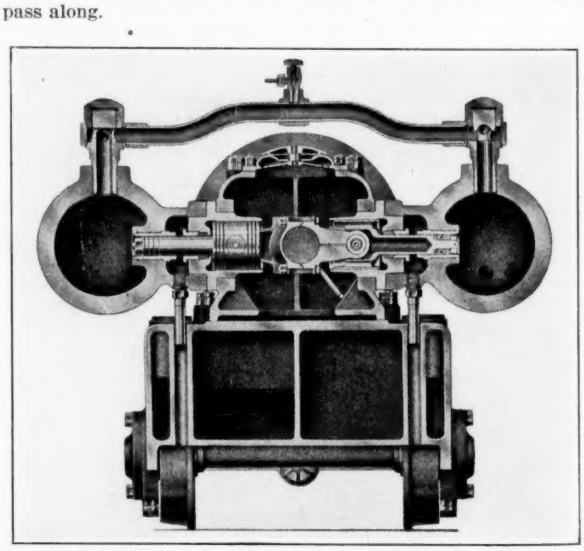
Wave transmission or sonic transmission is the name used alternatively to describe a sixth method in which are employed wave motions or pulsations set up in an enclosed column of liquid.

The liquid (usually water) is contained in a pipe connecting the apparatus generating the wave motions to the machinery which applies them to useful work.

Although apparently similar to hydraulic transmission, the underlying principle of wave transmission is totally and absolutely distinct. In hydraulics a continuous flow of liquid or motion of the liquid column as a whole invariably occurs whereas in wave transmission there need be no direct or continuous flow, the particles of the liquid merely pulsating backward and forward about a mean position.

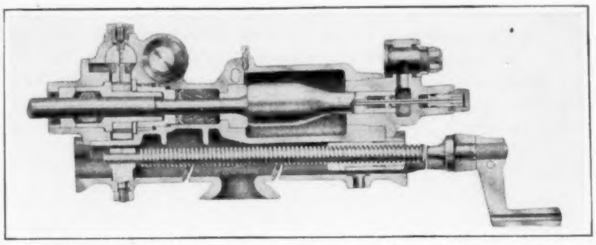
Water is compressible. Because the degree of its compressibility is very small compared to many materials in daily use, the idea that water was incompressible came to be accepted even by engineers. For the first time in the history of mechanics advantage is taken in wave transmission of the *elasticity* of water (and also of oil and other fluids) to transmit energy.

What occurs in wave transmission can be illustrated by simple analogy. In the ordinary speaking tube, pulsations set up in the contained air by the vibration of the speaker's vocal cords travel in the form of sound waves to the far end, where their energy is utilized in reproducing the vibrations in the ear of the listener. The column of air in the tube does not flow through the tube, but the particles are merely subjected to small movements to and fro as the sound waves pass along.



WAVE GENERATOR DEVELOPING 10 HORSE-POWER AT 40 CYCLES PER SECOND

Similarly in wave power transmission the pressure impulses set up by the wave power generator travel through the column of fluid contained in a metal pipe which connects the wave power generator to the wave power motor. There is no continuous flow, the fluid progressively moves forward and backward about mean positions. The wave thus travels through the column of liquid and gives up its energy to the motor at the far end. The motor is a simple mechanism for converting the waves of energy into any desired mechanical action.



LONGITUDINAL SECTION OF A WAVE POWER ROCK DRILL

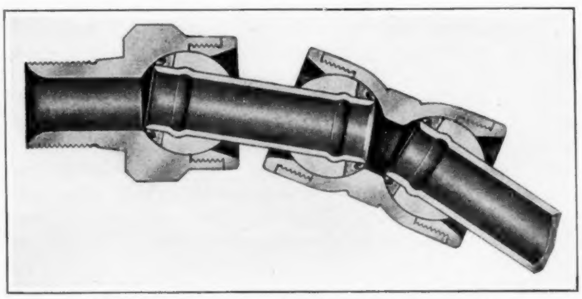
Taking the simplest form of wave transmission imagine two cylinders fitted with plungers, the cylinders on the underside of the plungers being connected together by a long pipe completely filled with water.

If one of the plungers is moved rapidly up and down it will set up at each downward stroke waves of compressed water, which, traveling along the pipe at the speed of sound (about 4,800 feet per second) will exert their energy on the plunger at the far end, and if this be suitably loaded, a simple reciprocating motion will be produced in exact synchronism with the reciprocations of the first plunger.

Wave transmission equipments are inexpensive to manufacture, simple in construction, and practically "foolproof" in operation. They consist of a wave generator, a wave motor and a wave transmission line.

The wave generator consists of one or more metal cylinders each fitted with a piston connected by a crankshaft to any type of high speed prime mover such as an ordinary steam or internal combustion engine or electric motor.

The wave motor consists of one or more metal cylinders each fitted with a piston, designed to receive the power wave at the intake end. The other end of the piston is suitably connected to the tool or other mechanism desired to be operated. The simplest application is found in such appliances as rock drills and riveting hammers where the piston is used as a floating hammer and strikes directly on the shank-end of the drill steel or rivet snap.



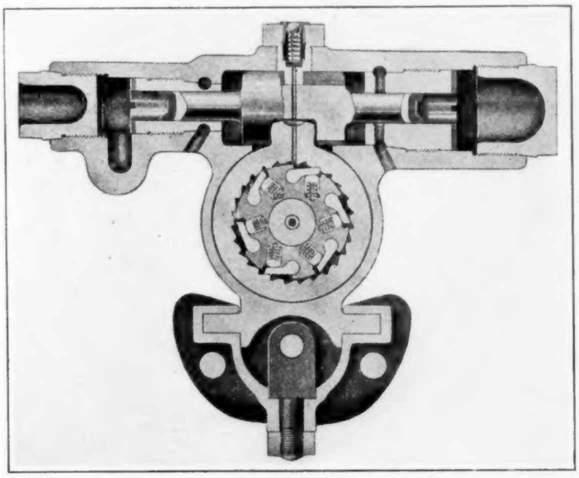
DETAILS OF THE FLEXIBLE STEEL PIPING

The wave transmission pipe line consists of ordinary rigid or suitable flexible piping used to contain the liquid which extends from the wave generator to the motor, and is referred to as "the liquid column." Various kinds of fluid may be used, from water to heavy oil. The highest transmission efficiency is however obtained through water.

In many ways electricity offers an excellent analogy to explain both wave transmission and hydraulics. Ordinary hydraulics being represented by the continuous current and wave transmission by the alternating current systems.

From the scientific and practical point of view one of the most interesting facts about wave transmission is this similarity in many features to alternating current electrical transmission. The points of resemblance are not mere coincidences. They go to prove the important fact that this purely physical method of transmitting energy is closely allied and is for all practical purposes a sister method to the alternating current electrical system. Anyone with a knowledge of electricity will find it easy to understand wave transmission. The laws and formulæ of wave and of electrical transmission coincide to the extent that they are nearly interchangeable. Most of the phenomena of electricity have their parallel in wave transmission. For instance there are direct equivalents for volts, amperes, frequency, angle of phase, induction, inductance, capacity, resistance, condensers, transformers, single-phase or poly-phase systems. In both systems there are used generators, rotary and reciprocating motors, and heating apparatus, transmission lines, etc.

In one of the accompanying illustrations is shown a sectional view of a wave generator developing 10 horse-power at 40



SECTION THROUGH THE MECHANISM THAT REVOLVES THE DRILL STEEL

cycles (2,400 per minute). The same generator is shown complete in the general view operating a wave power rock drill through a line of flexible piping.

Two spherical hollow steel castings shown in the sectional view are termed "the capacity." The disposition of these vessels on either side of the crankcase balances the forces on the crankshaft. This ensures freedom from vibration and quiet running at high speeds. The vessels are connected by a pipe at the top, the function of which is to equalize the pressure in each and enable the whole energy of the generator to be taken from either vessel. At the highest point of the balance pipe is a small needle valve for releasing any air that may get into the system. This is only required for a few seconds when starting up.

The bed plate of the machine is a substantial iron casting, containing the oil and water tanks. Each tank is filled through detachable fine gauze strainers and has a float and level indicator rod.

The rock drills operated by wave power have an incorporated water feed for washing the debris out of the hole, etc., the water being taken from the pipe line which transmits the power wave. Furthermore, there may be an accidental leakage in the pipe line. As one or more pipe lines are directly connected to the capacity, the volume of water in the latter would thereby be diminished. Therefore, an automatic varia-

ble delivery pump is provided for charging the system and replenishing the water in the capacity and pipe line.

Screwed into the left-hand spherical vessel is an inlet charging valve actuated by pressure difference. When the minimum pressure in the capacity is greater than the pressure of the pump this is closed; but the instant that the pressure in the capacity falls (due to loss of water) lower than the pump pressure, it opens. Thus, the inlet charging valve is automatically operated and controls both the rate and time of delivery of the water into the system.

The wave-power rock drill is similar in general proportions to a standard compressed air drill and may be fitted into a standard cradle. The drill steels are also interchangeable with standard air drills. Details of the mechanism are shown in the sectional view.

The operation of the drill is as follows: The waves of energy are admitted to the hammer element through the control cock which is situated in the inlet piece. These waves of energy act on the end of the hammer, throwing it forward until the front end strikes the rivet snap. Surrounding the hammer is a chamber or space which is called a capacity. This capacity is completely filled with water and fulfils the function of a fluid spring. Owing to the difference in diameter between the striking end of the hammer and the piston end, a displacement takes place on the forward stroke of the hammer which compresses the water in the capacity, so that when the pressure in the line drops below mean pressure, the force acting on the annulus is greater than the force on the end of the hammer, therefore the hammer returns to its backward position ready to receive the next pressure wave. The capacity in conjunction with the hammer is designed to give the hammer a natural period of vibration equal to that of the generator, *i.e.*, 40 complete vibrations per second, or 2,400 blows per minute.

CARRYING 68 FEET OF ¾-INCH FLEXIBLE STEEL PIPING, TESTED TO 15,000 LBS. PER SQUARE INCH

A wave power motor is furnished for rotating the drill steel. This motor, which is of the displacement type, is incorporated in the drill body. The fluid reaches it from the main inlet, through a direct passage in the side of the drill. On the depression side of the wave, the pressure in the capacity is in excess of the line pressure, with the result that the piston moves back, causing the ratchet ring to engage with the pawls in the chuck, thus rotating the chuck and the drill steel.

The flexible steel pipe is of simple construction. The individual sections of any desired length are made from solid drawn steel tube with new type of spherical joint at the ends. The pipe as a whole can be coiled, bent or twisted in every conceivable position. The joint consists of a piece of steel formed with a spherical recess at each end into which fits a length of solid drawn tube, upon which is mounted the ball piece which accurately fits the spherical recess.

The ball piece is flatted on one end to receive the special packing ring which is made from materials suitable for any special purpose to which the pipe will be subjected.

A spherical seated nut is screwed into the double socket shoulders against the spherical surface of the ball piece and securely holds the pipe together. By simply unscrewing this nut the pipe can be taken apart, shortened or lengthened in a few minutes.

RECENT DEVELOPMENTS IN ELECTRO-PERCUSSIVE WELDING

FOLLOWING the original experiments of Mr. L. W. Chubb machines were built for welding wires by the electro-percussive process. Since these machines utilize the discharge of an electrolytic condenser as the fusing source its field of application is limited, as far as the size of the work is concerned: condensers of sufficient capacity to provide energy for welding large sections would be prohibitive in size. On the other hand, this method of welding gives perfect welds between like and unlike metals, even those of widely different physical characteristics.

Within the last year equipment has been developed which successfully welds stock up to ½-inch diameter, and large sizes will apparently offer no difficulty. In the new equipment stored electromagnetic energy replaces electrostatic energy. Establishment of a strong direct-current field in a reactance coil with a primary and secondary winding is followed by rupture of the primary current with the secondary circuit closed. Transfer of energy of the collapsing field to the secondary results and a subsequent separation of electrodes in this circuit establishes an intense arc. When the surfaces of the electrodes—the pieces to be welded—are sufficiently melted a hammer forges the parts together. The total time of the above operations is of the order of 1/10 second. Oscillograph records show that, for a weld of ⅜-in. diam., the maximum current is 2,600 amperes, arc voltage 30 volts, maximum watts 60,000, average watts 29,600, total time 0.094 seconds, energy 2,780 watt-seconds or .00077 kw.-hr.

Some of the advantages of electro-percussive welding are: (a) Saving of power of which about 1/16 is used of the amount required in butt-welding. (b) Saving of time. The operation is so rapid that the time of weld is practically negligible. Speed of production will, therefore, depend chiefly on time of handling the material and large output can be obtained by design of semi-automatic apparatus. (c) Welds of unequal sections. Necessary energy is concentrated in a very small amount of material and not dissipated in heating the whole stock. Consequently welds of unequal section are possible without preparation of surfaces or preheating of large piece. (d) Welds of unlike metals with widely different physical characteristics are made possible. (e) Welds without change of condition. Tempering or other treatments are not destroyed because heat is localized and rapid. (f) Welds uniform. After proper settings unskilled labor can produce uniformly perfect welds. (g) Finishing is unnecessary in some products and inexpensive in all because of small fin or flash.

Extension of the original process has met with gratifying success and when details of design are perfected a wide field of application for electro-percussive welding is expected.—Douglas F. Miner, *Journal of the American Institute of Electrical Engineers*, June, 1920, pp. 533-35.

The Path of a Shell

Determination of Meteorological Corrections on the Ranges of Guns

By Waldemar Noll

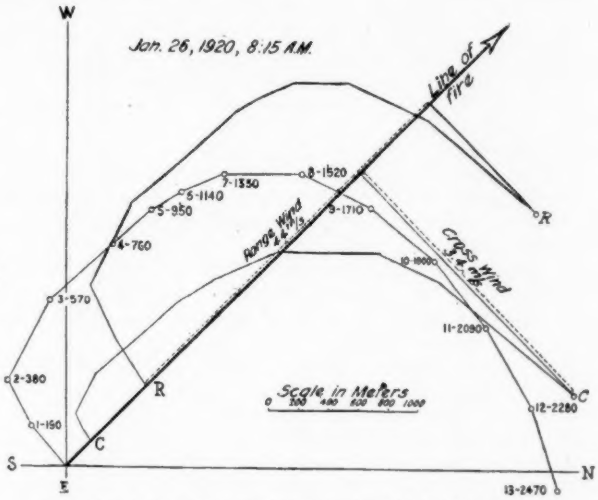
THE accuracy of modern artillery fire does not depend upon the marksmanship of the gunner as that term is understood in the firing of small arms. A man with steady nerves and a keen eye may be able to bring down a deer at 2,000 yards with a small rifle. Those physical qualifications, alone, however, are of small value if he is trying to hit a fort or an ammunition dump in the next county with a big gun. Under these conditions he is unable to see the target and so he is given the location on the map, literally the address, of the target and then by use of his range table he computes how he must point his gun in order to make a hit.

If there were no air it would be comparatively easy to determine the proper setting of the gun by the use of simple formulas. However the presence of air greatly complicates the problem. In the first place, the air offers a resistance to the projectile which diminishes the velocity and consequently decreases the range. In the second place, because of the rapid rotation of the shell caused by the rifling of the gun the air causes a drift to either the right or left of the original line of fire, depending on the direction in which the shell is rotating. It is a similar rotation that causes a baseball to curve. Even with the presence of air the problem would be much simpler if there were no variations in the atmospheric conditions. However the atmosphere changes daily, hourly, in temperature, barometric pressure, cloudiness, rain, humidity and wind. All of these changes, which actually constitute our weather changes from day to day, have a greater or smaller effect upon the range of the projectile and the artillerist must know how to correct for them if he expects to hit his target. A wind along the line of fire will decrease or increase the range depending on whether it is opposing or following while a a wind across the line of fire will affect the drift. A change in the temperature, pressure, or humidity of the air brings a change in the air density or weight of the air which in turn affects the retardation and consequently the range of the projectile. Temperature variations also change the elasticity of the air and thereby have further influence on the range.

Any independent calculations of the meteorological corrections immediately before the firing would be very impracticable, principally because it would take too much time. So the artillerist is supplied with range tables which give the range and deflection for any setting of his gun when normal atmospheric conditions exist. This range is called the normal range. In these tables are incorporated corrections for meteorological conditions when these are not normal. When the existing meteorological conditions are supplied to the artillerist in suitable form he determines the corrections to his normal range very easily by reference to his range tables. The meteorological data is supplied in terms known as "Ballistic Meteorological conditions," namely, "Ballistic Wind," "Ballistic Density," and "Ballistic Elasticity." The determination of these factors will now be taken up.

Previous to the World War, the principal corrections for meteorological variations were determined from surface conditions only. But unfortunately, surface conditions seldom represent air conditions prevailing between the surface and the maximum altitude reached by the projectile in its flight. Winds aloft usually have different directions and different velocities from those on the surface, while the temperature decreases with altitude are often very irregular. Because a shell spends most of its time of flight in the upper regions it becomes necessary to take into account the meteorological factors aloft in order to determine the corrections properly.

The wind aloft is obtained by releasing rubber pilot balloons inflated with hydrogen gas, and observing them with specially constructed transits, known as aircraft theodolites, located at two points several miles apart. At equal intervals of a minute the horizontal or azimuth angles and the vertical or elevation angles are read on the balloon by observers stationed at both instruments. An azimuth angle is the angle between some established direction, such as true north and the horizontal projection of the balloon. The elevation angle is the angle between the surface of the earth and the line joining the instrument and the balloon. The horizontal distance and the altitude for the successive minutes are determined by triangulation and a flight map is made. This map shows the horizontal projection of the path of the balloon and the height at the end of each minute. By measuring on the flight map the distance the balloon travels in a minute the wind velocity is obtained for the corresponding altitude and by noting the direction the balloon is going the corresponding wind direction is obtained.



MAP OF A BALLOON FLIGHT SHOWING CROSS WINDS

The accompanying sketch is a map of a balloon flight made at Aberdeen, Maryland, on January 26th, 1920, and shows the horizontal projection and altitude of the balloon at the end of each minute. The wind direction on the surface was northeast and then it gradually swung around to southwest. This flight illustrates that in correcting range erroneous results would be obtained if surface winds were used in determining the corrections. Temperature aloft is obtained by means of kites, kite balloons or airplanes. In the first two cases self-recording instruments known as meteorographs record the temperature at the various altitudes during the ascent and descent. When an airplane is employed a meteorological observer accompanies the pilot and at regular intervals of altitude reads the temperature from a thermometer which is fastened to a strut of the plane. Pressure aloft is readily determined from surface pressure by use of formulas; while humidity aloft, which is relatively unimportant, is estimated from surface humidity. Knowing temperature, pressure and humidity aloft, the air density is computed from the standard gas laws of Charles and Boyle.

However, because of the complexity of the trajectory or path of a shell, the meteorological conditions at various altitudes within the maximum ordinate have effects which are not at all proportional. The maximum ordinate of a trajectory is the maximum altitude reached by a shell in its flight. Sup-

pose a shell ascends to a height of 1,000 meters. It is entirely possible that the wind between 500 meters and 1,000 meters will have twice the effect of a wind with the same direction and velocity between the surface and 500 meters. Thus we see for the above case it would be necessary to give the winds in the upper half twice the consideration given to the winds in the lower half. Likewise some similar disproportional effect holds true for density and temperature. A definite and complete explanation as to why meteorological variations should be specially considered at the various altitudes would take us too far into study of ballistics. However, a few of the more important reasons may be stated. In the first place a shell spends more time in a given zone of altitude near the summit of the trajectory because of its lower vertical velocity than it spends in an equal zone nearer the surface of the earth, and thus the meteorological factors aloft have more time to affect the shell. Secondly, because of the retardation of the air and the pull of gravity a shell has a continually decreasing velocity as it proceeds and a change in wind, density or temperature at a low velocity has a different effect from that of an equal change at a higher velocity. A combination of these two principles brings about an almost infinite number of ways in which meteorological data at various altitudes may be considered.

The proper considerations that the meteorological factors at the various altitudes should be given are obtained from curves known as weighting factor curves. These curves are computed for the various guns by means of a series of differential corrections that cannot be discussed here. These curves are different when correcting for the various meteorological factors. For instance, the density and wind weighting factor curves are not identical. Likewise the curves vary for the different types of firing even when correcting for the same meteorological variation. For instance, the wind weighting factor curves for the 75 m/m gun and the 16-inch Naval Railroad Mount are not at all similar. There are distinct curves for the same gun depending on whether or not it is fired at a high or low angle of elevation or whether it is fired at a high or low muzzle velocity.

The methods followed in the determination of "Ballistic Winds," "Ballistic Density" and "Ballistic Elasticity" will now be taken up. These factors are determined by the Meteorological Service and are transmitted to the artillerist.

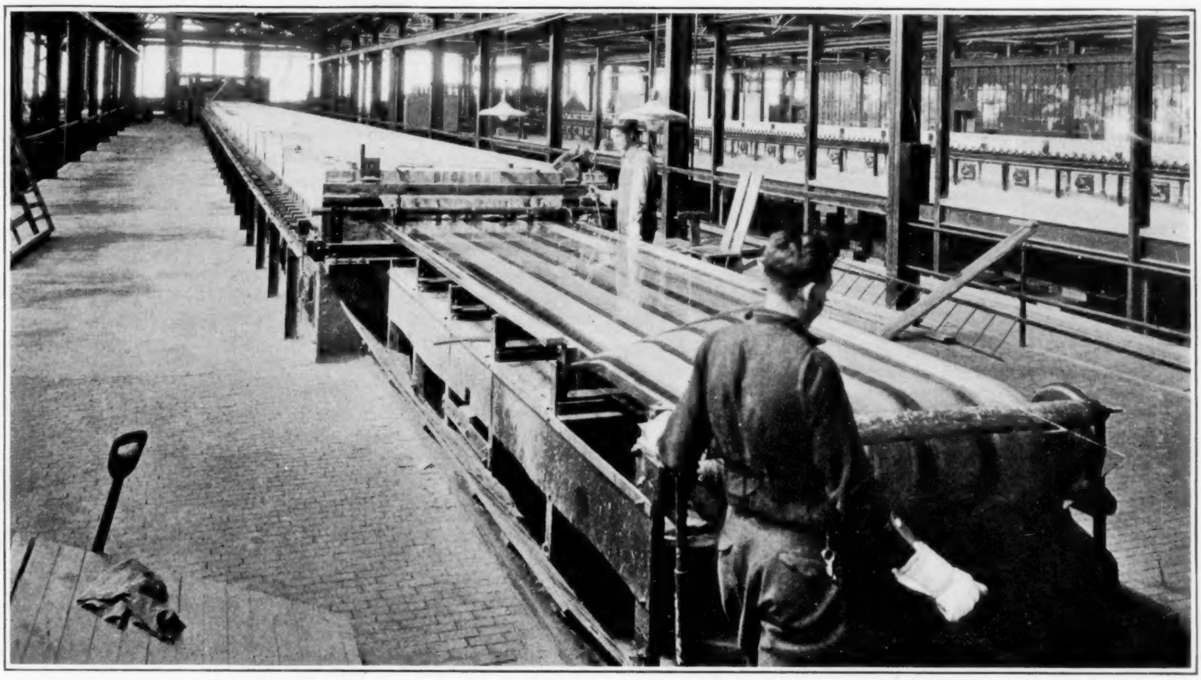
The range wind is the component of the wind parallel to the line of fire and the cross wind is the component perpendicular to the line of fire. As there are separate weighting factor curves for range and cross wind it is necessary to compute both range and cross ballistic winds. The velocities and azimuths of the wind aloft at equal zones of altitude are obtained by observing the flight of pilot balloons. For the particular gun to be fired and for the definite range to be obtained each altitude zone has a weighting factor for both range and cross wind. The range wind weighting factor for each zone is multiplied by the wind velocity for the corresponding zone and a column of values established. On a plotting board a line of fire is laid out. Beginning on any point on this line of fire a line whose length is equal to the product of weighting factor and wind velocity for the first zone, is drawn parallel to the wind direction for the first zone. From the end of this line a second line is drawn parallel to the wind direction for the second zone with a length equal to the product of the weighting factor and the wind velocity for the second zone. This process is repeated until the values for all the zones are plotted. From the final point determined a perpendicular is dropped to the line of fire, thereby completing a polygon. The distance from the initial point on the line of fire to the foot of the perpendicular equals the range ballistic wind. For the cross ballistic wind a similar procedure is followed except that cross wind weighting factors are used and that the actual length of the perpendicular equals the cross ballistic wind. The values of the ballistic wind are given in meters per second. The sketch gives a graphic illustration of ballistic wind computations. In the range table for the particular gun to be fired there is found the effect of a one meter per second wind on the range. For instance, for a range of 11,000 meters for the 75 m/m gun a one meter per second range wind will increase the range 42 meters. Had the ballistic wind been 10 meters per second, and following, the artillerist would have overshot his target 420 meters, about a quarter of a mile, had he not made a correction for wind. Likewise a ten meter per second ballistic cross wind to the right would cause the shell to fall 240 meters, about a seventh of a mile to the right of the target. Thus it can be seen that wind has a considerable effect on range and the artillerist allows for this effect by changing the setting of his gun. The whole procedure, while far more complicated, is similar to the allowance a fielder makes for wind when throwing a ball in to the catcher.

As in the case for wind, the air densities at various altitudes within the maximum ordinate have effects that are not proportional, and for that reason density weighting factors must be used in order to weight or consider the density at various altitudes properly. After the air density aloft is determined the values for the various altitudes are weighted by use of the proper density weighting factor curves and a value for "Ballistic Density" is found. This value is then compared with the normal density and a correction for range is made, if there is a variation from the normal density. When the range for the 75 m/m gun is 11,000 meters, a ten per cent increase in density would decrease the range 535 meters or about a third of a mile. A variation in density due to a change in temperature from a winter value of 0°F. to a summer value of 90°F. would increase the range for the above 75 m/m 1,070 meters or about two-thirds of a mile.

Under the consideration of air density we saw that the temperature has an influence on the range in that it changes the air density and consequently the retardation of the shell. However, temperature has an effect entirely independent of the air density effect in that it changes the elasticity of the air. A change in the elasticity of the air causes a change in the velocity of sound which in turn affects the range, as will be seen. The retardation of a shell is comparatively regular until its velocity approaches that of the velocity of sound. Then the retardation is greatly increased due to the fact that a part of the energy of the moving shell is dissipated as sound and thus the range is decreased. The muzzle velocity of a shell may be well above that of the velocity of sound but as the shell rises and progresses the velocity gradually decreases until it is equal to that of the velocity of sound. Now a change in the elasticity of the air may increase the velocity of sound so that the velocity of the shell may be nearer to the velocity of sound than what it would be under normal conditions. Secondly, in some other type of firing a change in the elasticity of the air may decrease the velocity of sound so that the velocity of the projectile will not be as close to the velocity of sound as it would under normal conditions. Thus the range would be increased. Therefore it is seen that the elasticity of the air throughout the maximum ordinate must be known in order to correct the range. The elasticities at various altitudes are weighted by appropriate weighting factor curves and a term known as "Ballistic Elasticity" is obtained and is used when correcting for range.

When the muzzle velocities are so high that the velocity of sound is never approached or when the muzzle velocities are below the velocity of sound no appreciable elasticity corrections need be made. When the range for the 75 m/m gun is 11,000 meters a change in "Ballistic Elasticity" caused by a change in temperature from a winter value of 0°F. to a summer value of 90°F. will increase the range 490 meters, about three-tenths of a mile.

This discussion is an attempt to explain the elementary principles of science involved in the problem and gives the steps followed on ordnance proving grounds when establishing range tables.



TAKING OFF GLASS AT THE END OF A SHEET DRAWING MACHINE

Modern Glass-Making*

Putting the Glass Industry on a Scientific Basis

By E. Ward Tillotson

Assistant Director of Mellon Institute of Industrial Research

GLASS and glassmaking ever have had a peculiar appeal to the imagination of all peoples. Glass, possessing many of the attributes of precious jewels and in addition possessing the susceptibility of constructive formation, is particularly adapted not only for articles of use but also for pieces of art in which the form, decoration and coloring reflect the artistic sense of the glassworker. Glassmaking as an art practiced in secret for centuries has been surrounded with the glamour of mystery and the masters of the art have enjoyed the patronage of royalty and the perquisites of the nobility.

DEVELOPMENTS DUE TO ENGINEERING

During the last two centuries, however, conditions incident to the advancement of civilization have swept away many of the mysterious formulas. The establishment of the glass industry in this country marked the beginning of scientific advancement in the technology of glassmaking: the economic situation prevailing in a civilization such as ours makes impossible the maintenance of a great industry in a state of technical secrecy. It is not to be inferred that the industry is free from ignorance and prejudice or that glass manufacturers do not jealously guard certain secret processes, but it is only just to say that in no other country are glass factories more open to inspection for casual visitors and for business competitors. The glass manufacturer in general realizes that an exchange of ideas is of greater value to both parties than any doubtfully guarded secret could be to either one.

The first advances in glassmaking in the United States and the most widely known American contributions to the industry consist in the applications of mechanical appliances and the making automatic of many glass-making processes. For example, the pressing of glass, an American invention of one hundred years ago, has passed successively through hand-fed, hand-operated presses, hand-fed power-operated presses, and now certain pressed glass articles are manufactured by automatic machinery which carries out the operations of "gathering" the molten glass, pressing the article, transferring it to and conveying it through the "leer."

IMPROVEMENT IN BOTTLE MAKING

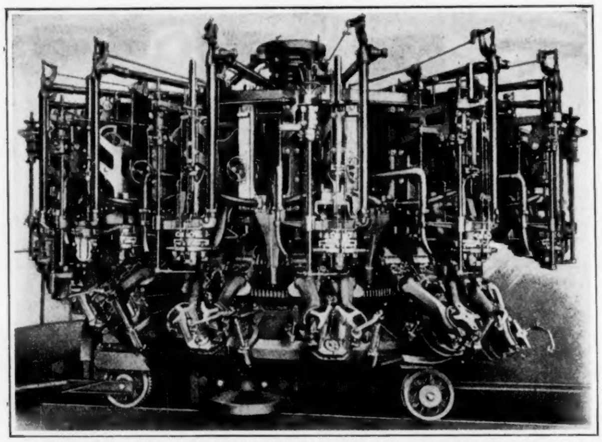
A similar development has taken place in the manufacture of bottles, bulbs for incandescent lights and other articles involving pressing or blowing or even a combination of the two operations. In the window-glass industry the process, though of more recent date, has been equally brilliant and of far-reaching importance. Machines not entirely automatic, to be sure, draw huge cylinders from a pool of molten glass, and not only is the product of a far better quality than that produced by the old "hand-blowing" process, but the great economic saving marks the introduction of machine-drawn window glass as a revolutionary achievement. Of the very recent developments in machine-made window glass mention should be made of a process in which "endless" flat sheets of glass are drawn and passed continuously through the leer. It is considered that this machine is an assured success. Obviously it possesses certain advantages over the cylinder machines, not only by reason of its continuous operation but also because the expensive operation of "flattening" is eliminated.

*Reprinted from *Chemical and Metallurgical Engineering*, Vol. 23, No. 10, Sept. 8, 1920.

LITTLE PROGRESS IN PLATE-GLASS INDUSTRY

The plate-glass industry has not experienced any spectacular developments of the nature of the inventions just mentioned; the operations as carried out at present are fundamentally the same as those of Thevart in 1688, with, of course, modern furnaces and leers and mechanical appliances for handling the glass in the several operations. This particular industry has been slow to develop in this country, but in recent years the requirements for windshields and other plate-glass fittings for automobiles have greatly stimulated the production of plate glass.

Mention should be made of "wire glass," which is manufactured by processes analogous to those employed in plate-glass manufacture. It is an American invention and represents perhaps the greatest advance in the application of plate glass for special purposes.



FIFTEEN-ARM AUTOMATIC CAPABLE OF PRODUCING 350 GROSS OF PINT BOTTLES PER 24 HOURS

In the other glass industries American manufacturers have had the advantage of large resources of raw materials of a high degree of purity and of cheap clean fuel (natural gas); and while these factors have contributed to maintain the quality of American glassware on a par with that of other countries, revolutionary developments in certain lines have not been made.

RÔLE OF THE CHEMIST AND PHYSICIST

It is, therefore, evident that American contributions to the advance of the glass industries have been largely from the engineering standpoint. It is not to be supposed, however, that the chemist and the physicist have entirely neglected these great industries. In fact, the part of these scientists has been of greater importance than is commonly supposed or acknowledged. Little has been written of the chemist's accomplishments, except, perhaps, in connection with the development of optical glass during the past few years.[1] Chemical contributions have been isolated, sporadic and, unfortunately, dimmed in the shadow of a general policy of secrecy which has resulted partly from tradition and partly from fear of legal complications. Such conditions do not make for real scientific progress in this or any other industry, but it is believed that the present is a period of transition and it is certain that great opportunities exist for the chemist and that his work in the future in conjunction with that of the physicist and engineer will transform the whole aspect of glass technology. The problems which are to be solved include the basic principles of all the operations involved and of the materials employed. The problems in connection with refractories, furnaces, fuel and raw materials are shared in common with all branches of the glass industry.

THE RÔLE OF THE REFRACTORIES

The pots in which glass is melted and the walls of the tank melting furnace are made from certain refractory fireclays. The curious situation is therefore presented of melting one type of silicate in a container composed of another type of silicate which is slowly but surely dssolved by the molten material. Unfortunately, none of the common metals possesses properties satisfying the requirements for these containers, and such substances as are known to be insoluble in molten glass have not yet been bonded successfully with an equally refractory and insoluble cement. The proposal has been made that the tank be constructed as a water-jacketed iron box. Walls of chilled glass would thereby be formed of the same composition as that of the glass to be melted. This would appear to be an almost ideal solution of the refractory problem, but in trial certain faults have been disclosed. Between the walls of cool and comparatively rigid glass and the channel of flowing molten "metal" there exists a zone in which the conditions are favorable for devitrification. Crystallization of some of the components of the glass occurs and these crystals are gradually carried to the working end of the tank and appear as defects in the finished product. When the chemist has succeeded in preventing devitrification in glasses of the type melted in tanks, this water-cooled tank will perhaps have a large field of usefulness.

THE POT AN IMPORTANT FACTOR

The use of green or partly burned pots and blocks is not to be considered as entirely satisfactory. Even if the pot is burned carefully in the pot arch, it is subjected to a higher temperature in the furnace. As a result, the back wall and crown are more thoroughly vitrified and subjected to considerable shrinkage, while the bottom and front walls are protected from the heat and remain more porous and do not shrink. This condition results in the introduction of large strains in the pot walls and contributes to a lessened life by reason of breakage and for other causes.

Certainly the several operations involved in the manufacture of the pot or the block are of an equal importance with the kind of clay employed and a thorough understanding of these operations would be of inestimable value to the glass industry.

The historic glass furnace is illustrated by the open pot and covered pot furnaces in common use. These furnaces are admittedly inefficient and cannot be considered as satisfactory from any standpoint. With covered pots, especially, the heat necessary for melting the glass is generated within the furnace and must traverse the walls of the pot before it can perform its work. Even with efficient regeneration—and few of the installations can be so classified—the waste of heat is sufficient to justify the most serious consideration. Because of this the use of pots except for melting certain kinds of glass[2] may be expected to decline.

The introduction of the tank furnace has made possible the quantity production of glass which has justified and prompted the development of automatic machines. This type

[1]For a concise review of the contributions of the chemist to the optical glass industry see A. A. Houghton, *J. Ind. Eng. Chem.*, Vol. 7, p. 290 (1915). In speaking of developments in this country Mr. Houghton says: "America's contributions to the development of the glass industry, chiefly in methods of working and handling the molten glass, are epoch-making in character; along more strictly chemical lines creditable work has been done, as instanced by the Tiffany or Aurene glass, the selenium red, and others. Aside from optical glass, on which a beginning is being made, the glasses produced in this country probably are fully equal in quality and variety to those produced abroad; and in some respects America is forging ahead." For a recent report on the status of the optical glass industry, see R. J. Montgomery's "Twenty-three Types of Optical Glass," *J. Am. Ceram. Soc.*, Vol. 3, pp. 404-10 (1920).

[2]For example, most of the colored glasses and other special glasses are used in too small a quantity to justify the use of a tank in their production. The more intensely colored glasses, in addition, are so impermeable to radiant heat that they may be melted only in pots; and pots are thought necessary for chemical reasons in the making of ruby glasses.

of furnace represents something of an advance over the pot furnace from the standpoint of heat efficiency, but still leaves much to be desired. The tank was used first for window and bottle glass, but has been adapted to melting "lime flint" or "crystal" glass, and the indications are promising that even "lead" glass may be produced in it commercially; it will undoubtedly be employed for any glass whenever the volume of production justifies.

The melting of glass by electrical energy has been the subject of much experimentation, and it is understood that elaborate trials of this principle now are being conducted. Molten glass is a fair conductor of electricity; and if the electric current can be passed through the molten glass and the heat be thereby developed within the charge, it appears that the optimum conditions of efficiency will be realized.

RAW MATERIALS

The great developments of the glass industry during the past forty years have been associated with the supplies of natural gas. This fuel, which was ideal for the use of the glass manufacturer, is failing rapidly and even now is to be considered as a pleasant memory. The question of fuels is largely an economic one. Glass factories always have been located near the supplies of cheap fuel, but with the improvements in the manufacture of producer gas this consideration will perhaps be of less importance in the future. The necessity in melting and annealing glass of an ashless fuel and one as free as possible from sulphur and other impurities probably excludes all solid fuels except as they are gasified in the producer; and while in a measure successful, the use of fuel oil does not appear to become general by reason of its growing cost and of its lessened availability. Improvements in the design of furnaces and of regenerating systems which will admit of a more efficient application of the fuel and of a better control of combustion will be of material aid in conserving our fuel resources and in making for economy in the industry.

The American glass manufacturer is favored with large supplies of raw materials possessing a high degree of purity. The sand, lime and soda which are available are not surpassed in any country. Good as the sand is, however, it contains small amounts of extraneous minerals, containing iron, titanium and other color-producing oxides, the economic and complete removal of which would materially lessen the "color" problem in the manufacture of the finer grades of glass.

The importance of the chemical control laboratory should be pointed out in this connection. Automatic machines demand "metal" of constant viscosity, heat conductivity, "hardness"[3] and other physical properties. It is therefore important that the composition of the glass be maintained as constant as possible from day to day. When it is considered that not only does the composition of the raw materials vary in different shipments but that some of the materials—for example the "lime" (CaO with more or less MgO)—change in composition during storage by reason of absorbing moisture or carbon dioxide, it is evident that the scientific production of even more ordinary kinds of glass necessitates constant and adequate chemical control.

The substitution of limestone for burned lime, the addition of feldspar or other aluminiferous minerals to the batch and the use of other glassmakng materials are problems not only of economic importance but are also essential in scientifically adapting the properties of the glass to its intended use. A new source of potash would be of benefit to certain branches of the glass industry.

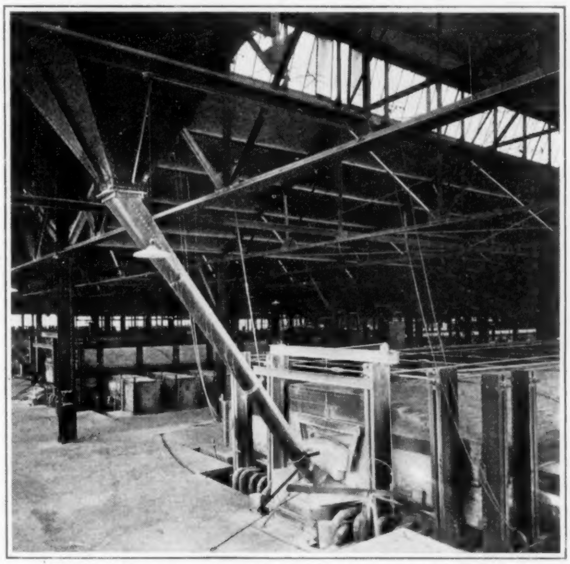
PROBLEMS IN SPECIAL BRANCHES OF THE INDUSTRY

Each branch of the glass industry has its own individual problems. In the present state of the window-glass industry, for example, there are many problems in connection with eliminating the relatively minor difficulties consequent on the creation of a new and great manufacturing procedure.

Similarly in the machine production of bottles and "packers" the majority of the problems of immediate importance are related to the perfecting of the several processes which are competing for supremacy. The situation is one of mobility and of rapid progress, and it appears that the man of scientific training may have an important part in the developments of the future which will determine whether each of the automatic and semi-automatic machines will have a particular use of its own or one of them will prove to be so superior as to be of universal application.

The plate-glass industry is waiting for fundamental developments. At present the glass is melted in open pots and from these is poured on to the casting table, on which it is rolled. A means for conveying glass melted in a tank furnace to the casting table without the introduction of bubbles or other defects would almost revolutionize the industry. The mechanical appliances for handling the huge plates of glass have been highly developed and important innovations in the annealing process have been made, but the procedure employed in grinding and polishing, in spite of recent improvements, is impressive in its awkwardness, complexity and lack of economy. A fundamental solution of this technologic problem may perhaps be the deciding factor in the future of the polished plate-glass industry.

In all these industries, as well as those represented by a smaller volume of production, there is need for a wealth of scientific data of a chemical and physicochemical nature.



FILLING END OF A LIBBEY-OWENS GLASS FURNACE

The chemical reactions taking place during melting require scientific investigation; the principles of annealing glass have not been wholly worked out, and the building of leers to apply these principles is necessary for scientific annealing. A better understanding of the physical properties of glass at all temperatures and of the relation of the chemical composition to the physical properties is of real importance, not only in its fabrication in automatic machines but also in the development of new glasses or of glass for specific applications.

The adsorption of glass on glass surfaces and the behavior of glass to the solvent action of water and solutions are also of importance. A cheap glass of lesser solubility would find many uses and a glass of great mechanical strength would be desirable for containers which are to be used repeatedly.

To mention all the problems of the glass industry would be to discuss every detail in the manufacture and uses of glass. It should be mentioned, however, that a pink, red or ruby glass

[3]Since no glass has a definite melting point, the word "hardness" has been used to denote the temperature at which it possesses a prescribed viscosity.

SOME NOTABLE DEVELOPMENTS IN THE GLASS INDUSTRY

Innovation	Date	By Whom Introduced	Place	Comments
First glass factory in America	1608		Jamestown, Va.	For the manufacture of beads and bottles
Pressed glass	1827	A carpenter, name unknown	Sandwich, Mass.	The Boston & Sandwich Glass Co., Deming Jarves, mgr.
First plate-glass factory in America	1857		Williamsburg, N. Y.	Failed by reason of competition from France and Belgium
Lime-flint glass	1864	William Leighton, Sr.	Wheeling, W. Va.	This invention nearly extinguished the old flint industry.
First regenerative pot furnace	1865	James B. Lyon	Pittsburgh, Pa.	Built at the O'Hara Glass Works, for use with producer gas
First continuous tank in America	1879	Poughkeepsie Glass Works	Poughkeepsie, N. Y.	For the manufacture of bottles.
First use of natural gas in melting glass	1882	Bradford Window Glass Co.	Bradford, Pa.	In 1884, gas was used for melting flint glass in the Riverside Glass Works, Wellsburg, W. Va.
Prepressed blank	1882	Philip Arbogast	Pittsburgh, Pa.	An important step in the development of the automatic bottle machines.
Continuous leer for window glass	1882	Cleon Tondeur	Dunhamville, N. Y.	Fox & Sons Window Glass Co. (the "rod" leer).
Continuous tank for window glass	1884	United Glass Works	Streator, Ill.	
Wire glass	1892	Frank Schuman	Tacony, Pa.	
Favrille glass	1892	The Tiffany Furnaces	Corona, L. I.	
Selenium ruby glass	1894	Nicholas Kopp	Pittsburgh, Pa.	
Flint glass melted in tank	1898	Charles H. Runyon	Rochester, Pa.	Keystone Glass Co.
Continuous leer for plate glass	1898	Marsh Plate Glass Works	Walton, Pa.	
Fire polishing cut glass blanks	1899	Michael J. Owens	Toledo, Ohio	
Automatic bottle machine	1899	Michael J. Owens	Toledo, Ohio	
Machine drawn window glass	1900	John J. Lubbers	Pittsburgh, Pa.	The American Window Glass Machine
Machine drawn shet glass	1903	Irving W. Colburn	Franklin, Pa.	The Libbey Owens Sheet Glass Machine.
Flowing device	1903	Homer Brooke	Jersey City, N. J.	Used in connection with automatic machines.
Continuous leer for flint glass	1908	Maryland Glass Corporation	Baltimore, Md.	The intermittent pan leer had been in use for fifty years.
Low expansion glasses	1915	E. C. Sullivan & W. C. Taylor	Corning, N. Y	Pyrex glass.
Hartford-Fairmont feeder	1915	Karl J. Peiler	Fairmont, W. Va.	For use with automatic machines.
Automatic tube machine	1916	Edward Danner	Toledo, Ohio	
Automatic bulb machine	1917	August Kadow	Toledo, Ohio	The Westlake machine producing bulbs for incandescent lights.

has not yet been produced in which color is constant throughout the operations and heat treatments which are involved. A highly colored red glass of permanent tint used in conjunction with the well-known blue glass, "powder blue," would form an ideal "decolorizer" and would be appreciated by the glassmaker. The use of colored glasses for signaling, for color screens in photochemical work and for goggles and spectacles to protect the eyes indicates the importance in the manufacture of these glasses of a scientific understanding of their properties, production and uses. The successful application of artificial illumination is associated closely with the glass used, and the scientific production of translucent and other glasses of the required properties offers a fruitful field of investigation for the scientist.

ACCOMPLISHMENTS OF THE CHEMIST

Examples of what the chemist already has accomplished in the glass industries will occur to any one who is familiar with this field of manufacture. The German scientist has received his share of glory in the development of the optical glass industry, but the American inventors have been given little publicity. The American contributions of "lime flint"[4] glass, and recently of new laboratory glassware, of glass of extremely low coefficient of expansion, of glasses of peculiar properties for particular uses, and, during the war, the rapid establishment of a whole optical glass industry, under the direct supervision of scientists from the Geophysical Laboratory and the U. S. Bureau of Standards, are noteworthy accomplishments and are indicative of greater achievements when the glass industry has been put on a scientific basis.

The responsibility for fulfilment of this condition rests equally upon the scientist and upon the industrialist. It is fair to conclude that the glass manufacturer is not yet convinced that the scientist has an understanding of his problems or the ability to solve them equal to that of his practical glassmaker. It is probably true that the chemist often has failed to produce results in the glass factory; it is also probably true that the glass manufacturer has not understood what he might expect of the chemist and has not had a sufficient comprehension of science to utilize the services of the chemist to the best advantage. It is evident, therefore, that a fundamental consideration in putting this industry on a scientific basis is a more adequate training of chemists and chemical engineers in glass technology. The number of our universities which offer courses in the chemistry of glass is distressingly small and there remains to be established in any school an adequate course in glass technology in which the knowledge of the practical glassmaker is correlated with the known principles of chemistry and physics. The opportunities offered in this field and the knowledge that men of scientific training will be required in the glass industries constitute the primary arguments for the establishment of such courses of training, and the assurance of coöperation on the part of the industrialist will be of material aid and is indeed necessary in the consummation of this desirable purpose.

Such a course in glass technology should not only develop men for research and control work but should also offer to the practical man an opportunity to gain such a knowledge of scientific principles as will be of benefit to him in working in sympathetic accord with the scientific men in his factory.

In this principle is undoubtedly to be found the reason for instances of failure of the chemist in the glass industries. The chemist has not been trained to understand the point of view of the men making glass and the practical man has not understood the point of view of the chemist. In many industries in which the professionally trained man forms an essential part it has been found advantageous to give him in the factory an additional special training in the particular business of that factory. The recognition by the glass manufacturer of the fundamentals of this situation will quickly react to his advantage. The work of the chemist, particularly if he is engaged in research, lies within a field which properly comes under the direct jurisdiction of the chief executive of the organization. It is notable that in those concerns which have made the best use of the chemist he has come into a position of high executive responsibility. One instance, of many, may be cited in which the chief of the chemical laboratories is one of the five principal officers who report directly to the president of the company. This method of organization does not presuppose that the president is a man of scientific training, but it does assume that he has an understanding of the relation of his business to the scientific principles involved.

It is not to be expected that even a large number of chemists working independently and in isolation in the laboratories of a large number of glass factories will, in the highest sense, put the glass industry on a scientific basis. Science supposes organization and experience has demonstrated that united efforts are more productive than equally intense but disposed expenditure of energy. The success which has accompanied the research laboratories established by associations of manufacturers in a united purpose for the common good may well be considered by the several glass industries. The establishment in England of the Glass Research Association under the auspices of the Department of Scientific and Industrial Research is to be taken as indicating the beginning of concerted effort to apply scientific principles to the manufacture of glass, an attitude of coöperation which is commended to the attention of the glass industries in this country.

[4]Invented in 1865 by William Leighton, Sr., of Wheeling, W. Va. Leighton used sodium bicarbonate in place of soda ash, which at that time contained quantities of impurities.

"Cold Light"

Luminescence, Fluorescence and Phosphorescence

By J. J. Birch, Ph.D.

DURING the last few years much time and study have been spent investigating the nature of chemical reactions. It was known to the early alchemists that two substances when brought together under favorable conditions would unite or combine, forming a resultant differing from the original substances; but not until recent years have tenable theories been formulated to explain the changes in composition and constitution which substances undergo and the alteration in properties which accompanies and gives evidence of those changes. The atomic theory seeks to explain chemical reactions by assuming that all matter is composed of infinitely small particles called atoms. They possess the power of attracting or holding on to other atoms and do not subdivide in taking part in chemical changes. The atoms of each element are homogeneous, but differ from other atoms of other elements. Each atom in turn is divided into positive and negative ions. A single ion often includes several atoms of different elements and bears an electric charge while an atom does not. The existence of an electric charge entirely changes the properties of the atom, as may be seen from the electrolysis of sodium chloride. Atoms of chlorine, tend in pairs, to form molecules of green chlorine gas. Ions of chlorine are colorless and repel each other because they possess like charges. In the practice of general chemistry the ionic relations are those most frequently met with. The atoms of the elements are considered to consist of aggregations of large numbers of electrons in a kind of "shell" or "body" of positive electricity. The positive electricity in a given atom is equal in quantity to the total negative charge of the electrons in the atom; the atom as such, containing no excess of either positive or negative electricity. The number of electrons in the atom of the element is considered to be definite and constant for the element, but the number varies as we go from the atom of one element to those of a second element, the number increasing with the atomic weight of the element. It is altogether likely that the atoms in a molecule of a substance already possess electric charges, so that, even while combined, their tendencies to lose or gain electrons are satisfied. It is also possible that the atoms are held together in the molecule by the electrical attraction of the opposite charges. These facts must be held in mind in considering the hypothesis of luminescence, phosphorescence and fluorescence.

The term luminescence is generally applied to that property possessed by a large number of substances of becoming luminous under the influence of light, or other forms of radiation. The term has been proposed to include all cases in which bodies give off light due to ignition. When produced by light, the phenomenon is accompanied by absorption of the incident light of certain wave lengths, the luminescence consisting of light of wave lengths differing from those of the excited light. It is difficult scientifically to demonstrate just what happens in absorption, yet the field narrows itself down to a tenable conclusion which seems to include all conditions. The spectrum as we know it ranges from the red at one end to the violet at the other. Each of these and the intermediate colors have a definite wave length analogous to the waves of the sea—some long and others short and choppy; some moving slowly and others moving rapidly, with an indefinite number of intermediates. Molecules of substances, because of their chemical constitution, can vibrate only in one frequency. Suppose that frequency to be equal to that of the exciting light. When a substance whose molecules vibrate at the same rate as the exciting light be brought into the region of the exciting light, the electrons in the molecule will start to vibrate. This is comparable to the vibrations of tuning forks of equal pitch, when one is brought, while vibrating, into the region of the one which is still. The one which is not in vibration will start to vibrate and when one is dampened the other continues to vibrate. This is exactly what happens in luminescence. Substances which have a definite wave length are excited into motion by others having the same rate of vibration. Those substances, which when in reaction, are at the red end of the spectrum, give us luminescence. In many cases luminescence occurs with almost imperceptible rises of temperature, and for that reason has been called "cold light." Many chemical reactions often occur at low temperatures, at which temperature light appears. This is called chemiuminescence. Production of light by fracture of crystals is called triboluminescence; by cathode rays, cathodoluminescence; and by solidification of a melt or a precipitation from solution, crystalloluminescence. Many chemical reactions likewise take place only, or more vigorously, in ultra violet, or light of certain wave lengths. $3\,O_2 = 2\,O_3$ takes place mostly in the ultra violet. $2\,O_3 = 3\,O_2$ takes place mostly in the ultra violet. $H_2 + Cl_2 = 2\,H\,Cl$ likewise takes place mostly in the ultra violet. $4\,HI + O_2 = 2\,H_2\,O + 2\,I_2$ takes place mostly in blue light, some in the ultra violet and none in the green or red. $Hg + (NH_4)_2\,C_2O_4$ $Hg_2\,Cl_2 + 2\,NH_4\,Cl + CO_2$ takes place mostly in yellow light and some in the blue light.

Albertus Magnus knew that the diamond when heated moderately became luminous. Also when calcite is heated below the red hot point, light will be emitted, and it will continue to be luminescent for some time after the heat is removed. This is called thermal luminescence. It is believed that the crystal absorbed light until molecular action was brought about and that it continued to glow until this molecular action ceased.

If the luminescence occurs only so long as the exciting light falls upon the substance it is called fluorescence. This likewise depends on absorption of certain rays of light. It may be defined as that property which some transparent bodies have of producing light differing in color from the mass of material; as when green crystals of fluorspar afford blue reflections. The light emitted by fluorescent substances is in general of lower refrangibility than the incident light. By measurement of the distribution of intensities of fluorescent light in different directions, relative to the plane of polarization of the exciting beam of light, it has been found that the direction of vibration of the light emiting particles is not uniformly distributed, and that the direction at right angles to the plane of polarization is preferably adopted by the vibrating particles. This gives us the key to the hypothesis of fluorescence. An atom, as has been previously stated, is regarded as a positively charged body on the surface of which are one or an indefinite number of negative electrons. When light is absorbed its energy is converted into kinetic energy of the electrons which fly off at a greater or smaller distance from the atom, stirring up potential energy. On the return journey of the electron or body of electrons toward the atom, the potential energy is converted partly into light, not necessarily of the same wave length as that absorbed. Thus, fluorescence is not due to a difference in color of a distinct surface layer, but to the power which the substance has of modifying the light incident upon it. Fluorescent bodies emit their characteristic light only while under the influence of the exciting illumination, while phosphorescent bodies are luminous for an appreciable time after the exciting light is cut off. It is there that phoresence is differentiated from fluorescence, for if the luminescence persits after the excitation is discontinued it is called phosphorescence.

The property of phosphorescence has been known from early times. Pliny spoke of various gems which shone with a light of their own. However the first discovery which attracted scientific attention was that of Vincenzo Cascarilo, a cobbler of Bologne, who discovered that certain calcium sulphide salts emitted light after having been exposed to the sunlight. A number of other substances which became luminous either after exposure to light or on heating were soon discovered. To this class of substances the general name of "phosphori" from the Greek φως and φόρος, bringing light, was given. In recent years, it has become necessary to limit the strict meaning of the word phosphorescence to those substances which, after exposure to light became self-luminous, even if for only a fraction of a second. Phosphorescence in this restricted meaning is most strikingly exhibited by the artificial sulphides of calcium, strontium and barium. If any of these are exposed either to daylight or to the ultra violet rays, they will shine for hours in the dark with a soft colored light, the color being dependent however upon not only the nature of the substance itself, but upon its physical condition and on the temperature. Thus calcium sulphide may be orange-yellow, yellow, green or violet, according to the methods of preparation and the material used. Becquerel found that the light given by a specimen of strontium sulphide changed from violet to blue, green, orange and yellow as the temperature during the corresponding periods of isolation was 20, 40, 60, 100 and 200 degrees Centigrade. The duration of the phosphorescent light may range from but a few seconds to many days.

There are many minerals which possess the power of phosphorescing but likewise there are distinct processes which they must pass through in order to bring out this property. Fluorspar, lepidolite and quinine will all phosphoresce when heated below the red hot temperature. Fused calcium chloride will glow when rubbed together. The crystallization of boracic acid after fusion and the crystallization of water on rapid freezing also shows phosphorescence. This property is also manifest in the cleavage of mica. The two split portions become electrified, one positively and the other negatively. Gelatin, celluloid, paraffin and ivory are phosphorescent at very low temperatures, but lose this property at ordinary temperatures. The final explanation of phosphorescence in inorganic substances is that when a phosphorescent body is exposed to light the energy of the light is stored up in some kind of strain energy and the phosphorescent light is given out during a more or less slow recovery from that state of strain. This is necessarily attended with a change in molecular structure or in specific heat. The sulphides of the alkaline earths lose the property of phosphorescence when subjected to heavy pressure. Many fluorescent solutions become highly phosphorescent when rendered solid by gelatin.

Phosphorescence is also noted to a large extent in marine organisms and nocturnal insects. In the jelly fish there is no organ specially set apart for the production of light; but the whole surface seems to glow. This property is useful at great ocean depths where no sunlight penetrates, and is known as the "Abyssal Theory of Light." Some deep sea fishes have well developed eyes, while others have well developed light producing apparatus. This serves both to attract the opposite sex and as a means of defence to marine creatures and also to nocturnal insects. In the glow worm (*Lampyris splandidula*) the male has two pairs of organs in each of two segments preceding the last to the abdomen, each organ consisting of a pale, transparent superficial layer which gives off the light and a deep opaque layer whose function apparently is less obvious, but which may serve as a reflector. The light emitted by different animals varies. The glowworms, fireflies, centipedes and annelids give off a green light. The Italian firefly a blue, while certain species of cleodora emit a red light.

It is found, in general, that the light emitted by marine creatures is either blue or a light green.

The case of phosphorescence in organisms has not been conclusively proven to science. In the glowworm the distribution of trachæ throughout the photogenic apparatus, and the fact that carbon dioxide extinguishes the light, while oxygen intensifies it, suggests that it is due to some slow form of combination, while the fatty contents of the luminous cells of this and many other animals point to the probability that a fat containing free phosphorus is the active agent in the process. Since a large number of luminous organisms retain their power after death and even dissection and subsequent moistening, there seems no necessity to adopt the theory that we have to deal with an instance of direct transformation of vital into radiant energy.

COTTON RESEARCH IN EGYPT

THE Cotton Research Board, Ministry of Agriculture, Egypt, has issued its preliminary report from the Government Publications Office in Cairo. Egyptian conditions are particularly favorable to the cultivation of cotton, and the types evolved there are well known everywhere for the quality and length of the fiber. This is accompanied by a high yield, which makes it an attractive crop for the Egyptian grower. The government there has recognized the unique importance of cotton to Egypt, and from time to time commissions have been appointed to study particular matters with reference to the welfare of the industry. There has, however, been no permanent organization, but at the close of the war the Cotton Research Board was established, and this board has been constituted in a way to bring together experienced workers in all branches of science which can contribute to the problem of cotton improvement. These include Agronomy, Botany, Entomology, Chemistry and Physics.

Four important field experiments have already been initiated by the board. These are the effect of the subsoil water level on cotton, reduced watering experiments, yield tests of nine varieties of cotton and spacing tests. To indicate the extent and thoroughness of the work it may be pointed out that nine varieties of cotton are being grown on the chess-board system at five stations. There will be 270 plots, and the minimum number of plants under observation in each plot is 100. Thus the Botanical Section of the Board will be called upon to count flowers and bolls on 27,000 plants at regular intervals during several months of the year. The Entomological Section is working on a basis that necessitates the examination of the entire yield of at least 300 plants on each plot. The collection alone of this amount of material requires the entire time of an expert for ten days, and to carry out the observations at only one of the five experimental stations requires that the bolls be picked from 16,000 plants, and each one of these bolls be separately packed in paper in order that the test relative to the loss due to the pink boll worm may be concluded.

Plant breeding methods are under way. The entomologist is studying the various types of injurious insects, and the physicist, in addition to field experiments, finds demands for his talents in the measurement of length, strength, thickness, uniformity and so on, of the cotton fiber.

The chemist is making a special study of the Egyption soil, is responsible for observations concerning subsoil water and manures, and in addition is charged with investigations on the composition of cotton seed and the nature of the changes which occur during storage.

The work undertaken is obviously of the right character and, as is pointed out in the report, lost opportunities cannot be retrieved immediately and good scientific work cannot be hurried. Research can very seldom guarantee results in advance, and an important research of this character, whether carried on in Egypt or America, is so essential that it deserves continued adequate support and a large measure of confidence, especially in its initial stages.

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

The National Research Council is a co-operative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

X-RAYS AND ATOMIC STRUCTURE

By Augustus Trowbridge

Professor of Physics, Princeton University, and Chairman of the Division of Physical Sciences of the National Research Council

IN the following article it is not proposed to tell again any part of the story of the discovery and application to practical use of the Roentgen rays. This story is known to most of the readers of the Scientific American Monthly, many of whom have had first hand experience of the extraordinary development during the past twenty-five years of the technique of X-ray photography as an aid to medical diagnosis. It is proposed however to introduce to the readers of this magazine a little known and yet profoundly significant field of scientific research which has been carried on by a small band of investigators who were not primarily interested in the direct utilization of Roentgen's discovery, but were rather interested chiefly in learning from the results of cunningly devised experiments what X-rays are.

The researches of these scientists have been successful even beyond expectations, for not only has the uncertainty (the reason for the X, the unknown quantity, in the popular name) been removed so that we now know that X-rays are invisible light rays of wave length only about one five-thousandths of that of visible light, but also in addition it has been found that in the X-ray we possess a key which has already unlocked some of the secrets of molecular and atomic structure and is likely to prove a pass-key into new realms of physical and chemical discovery. The scientific study of X-rays has led to what is almost the ability to see the atoms and molecules. This has come through the discovery, in the X-ray, of a kind of light as fine-grained, so to speak, as the fineness of the grain of molecular structure. Before the discovery of the X-ray and what its nature is it was as hopeless to attempt to "see" an atom as it would be to notice the effect of a few scattered corks on the surface of the ocean by looking for a change in the character of the great ocean waves that had swept by the corks. Now the state of affairs is similar to an attempt to locate the corks by their effect on a train of fine ripples in a quiet pool. By noting how shadows are formed behind the corks and how reflected ripples run back over the surface in front of the corks a very fair idea of the spacing and size of the corks themselves may be obtained. And so it is with the ultra-microscopic atom and the X-ray as analogues of the corks and the water ripples. The atom may be of the proper size to "scatter" the light (X-ray) of short wave length and be far too small to "scatter" appreciably visible light of wave length many times greater.

Early attempts to secure experimental evidence on the nature of X-rays showed that the only effects produced on them by matter which were at all similar to effects of matter on ordinary light were certain absorption and scattering effects and a careful quantitative study of these made it appear probable, though by no means certain, that X-rays and ordinary light were identical except for a relatively enormous difference in wave length.

X-rays proceed from the metal target (or anti-cathode) of the X-ray bulb, at which it is known that the electrons from the cathode of the bulb are suddenly brought to rest after having had a velocity of something like a hundred thousand miles per second. The X-rays proceed from the metal target in straight lines and their presence may fortunately be detected in a number of ways, one of which is their effect on a photographic plate.

Soon after the discovery of X-rays a careful study was made of how they are scattered by various substances and also how these scattered rays are absorbed by matter. It was found that there are two distinct kinds of X-rays which proceed from a body which is scattering them; one kind is called simply "scattered" X-rays and the other "characteristic" X-rays. These latter were found to have very remarkable properties which depend in a large measure on the atomic weight of the material which does the scattering and the "characteristic" rays themselves seem to proceed from the scattering body as though they were generated in the body itself and not merely reflected or even simply scattered by it. In fact the penetrating power, or the ability of the X-ray to traverse thin sheets of metal, increases with the atomic weight of the element from which it is emitted so that the "characteristic" X-radiation from any atom can excite the corresponding radiation of a lighter atom but not that of a heavier atom. A quantitative law was discovered which enabled one to predict the penetrating power of the "characteristic" radiations emitted by any element when bombarded by X-radiations coming from elements of higher atomic weight. These "characteristic" radiations were found to be independent of chemical combinations. The characteristic X-radiation from iron, for example, was the same as that from any of the iron salts. This indicates that the source of the "characteristic" X-radiation is the atom and not the molecule or molecular group. In fact, all the various phenomena of X-radiation make it appear highly probable that the X-ray is caused by atomic activity, and the study of X-rays has held out the promise that because of this we may learn something of atomic structure. This promise has been very amply fulfilled during the past few years.

The evidence furnished by the ordinary scattered X-radiation that X-rays were probably invisible light waves of very short wave length and the evidence that the "characteristic" X-radiation came from an atomic vibration which emits a wave whose length depends on the atomic weight furnished the idea underlying one of the most brilliant discoveries in modern science. The idea was this: Why not make the atoms themselves scatter these invisible short light waves since in the class of materials called crystals we possess natural scattering systems whose elements are atomic in size, and since we have reason to suspect that the wave length of both the "scattered" and of the "characteristic" X-rays is of the order of magnitude of the spacing of the individual atoms in the crystals.

This daring suggestion and the difficult mathematical formulation of the results which might be looked for in experiment is due to Dr. Laue, a professor of the University of Zurich, Switzerland, and his predictions have been verified, though the most fruitful results have come from the following up of an experimental procedure based on a greatly simplified theoretical

treatment of the problem by the English physicists, W. H. and W. L. Bragg. Due to the pioneer work of these scientists there have been opened up two extremely fertile fields of investigation: 1st, a highly accurate experimental method of study of the actual arrangement of the atoms and molecules in crystalline bodies, and 2nd, a powerful aid to the analysis of atomic structure which has been, since the days of the very beginning of science, the aim of the scientist in his study of inanimate nature.

It is hardly necessary to point out the extreme importance of research along both of these lines. Useful application of discoveries and important discoveries themselves may be and are made without much real knowledge of molecular and atomic structure, but it is absolutely certain that both discovery and invention in the chemical and physical arts will be increasingly certain as we approach nearer and nearer to a knowledge of how matter is constituted.

In actual fact the studies of crystalline structure and of the dependence of the X-ray characteristics on the atoms which emit them went on hand in hand, but for the purpose of a brief description of these studies it will be better to take up these two matters one after the other. It is evident that if the wave length of any single one of the "characteristic" X-rays be accurately known a study of the atomic arrangement of all crystals may be carried out by learning how the atoms of these various crystals scatter the given X-rays. The problem is analogous (though far more difficult) to that of determining the spacing of the line elements of a fine optical grating from a knowledge of where all of the diffracted images of a source of light of known wave-length are formed. The optical grating is the simplest conceivable type for in it we have a single series of lines repeated one after another in a row. The next more complicated type is illustrated in the fly screen where there is a double series of lines at right angles to each other, each repeated one after another in a row. The fly screen is thus a very simple two-dimensional grating or lattice. Now for more than a half century the student of crystallography has been working on a theory of crystalline structure, due to Bravais, which pictures the atoms of a given kind in a crystal at definite points on a minute lattice-like structure in three dimensions—a so-called "cell" or element of a "space lattice." To picture a simple form of "cell" very much magnified one can think of a safety match box with beads at each of its eight corners and then imagine the beads to be held in place by forces between them so that one can imagine the match box itself to be removed. In this picture the beads would represent atoms of a crystalline substance and their arrangement would constitute a simple "cell" of eight atoms. Similar "cells" adjacent to each other would have atoms in common so that any atom belongs to more than one "cell." With the assumption of a very small number of relatively simple elementary space lattices, crystallographers have been able to explain the existence of all the varied forms in which the great host of crystalline materials occur in nature. A crystal like rock salt, for example, which consists of atoms of sodium and atoms of chlorine, is pictured as made up of definite "cells" of sodium atoms, and, occupying the same region, definite "cells" of chlorine atoms. A substance like diamond, which is made up of only one kind of atom (that of carbon) is similarly built up of two interpenetrating space lattices each consisting of an arrangement of carbon atoms.

In what follows one can assist the imagination by thinking of a huge pile of exactly similar safety match boxes; for example, a million boxes piled up on a base formed by ten thousand boxes ranged side by side and end to end; that is, 100 box-lengths deep and 100 box-widths wide. There would be 100 such layers, each layer having the height of one box. On account of this regularity of piling it would be possible to pass a very great number of planes through the pile in such a way that these planes contain a number of box corners (atoms). Some of these planes would contain a great many corners to the square foot and some would contain very few. In the example given the vertical plane through the exposed box ends would contain the greatest number of corners (atoms) possible, and there would be ninety-nine other exactly similar planes parallel to this one and separated from each other by one box length. Other planes would exist which contain nearly as many box corners, but their relative spacing would be different. In general there would be a small number of directions through the pile in which parallel planes might be drawn so as to include a large number of corners (atoms) and these parallel planes would be quite definitely and regularly spaced throughout the entire pile.

In the crystal then there exist a great many planes, each of which contains similar atoms, but some such planes will contain the atoms much more thickly packed than other planes do. From these planes thickly studded with atoms we should expect the X-rays to be most copiously scattered, and we should expect them to be very little scattered from those planes which contain only a few atoms to do the scattering. But the scattering takes place not only from a single plane thickly studded with atoms but from a whole series of similar parallel planes, and the effect we may expect must depend on the spacing of these planes. If the planes are spaced in a certain way the effect of scattered X-rays of a certain wave length coming from each of the succeeding layers may all help each other and we may have a great amount of scattered rays, while if the spacing of the planes is a little greater or less it may be that the effects from neighboring planes offset each other, just as two or more trains of light waves may produce darkness or trains of sound waves may produce silence. To sum up then: By studying the scattering of X-rays from crystals it is possible to determine which of the planes through the crystal are thickly packed with atoms of a given kind and to infer what the spacings of such planes are throughout the crystalline structure. By using "characteristic" X-rays of known wave length and studying the manner in which a crystal scatters these rays as it is held in different positions, it is possible to map out the spacing of the atoms on the space lattices of the crystal and even more than this it is possible to map out in a similar way the spacing of the other atoms of the molecule of the crystal substance and so obtain an accurate model of the arrangement of the atoms in the molecule for all these substances which occur as crystals.

Since the discoveries of Dr. Laue and the Braggs and their co-workers the architecture of crystals has been laid open to what is almost direct examination and measurement. The crystallographer and metallurgist need no longer infer from the external forms of crystals what their internal structure may be. It should be now merely a matter of experimental detail for the metallurgist to learn definitely what happens in the heat treatment, tempering, aging, etc., of the crystalline metals. Because of this new tool for research in crystal structure a few interesting facts have already come to light: amorphous carbon really consists of minute graphite crystals; colloidal gold and silver consist of minute crystals so small that they contain but a few score atoms and yet these crystals are as perfect as the larger growths. A plausible reason for the hardness of certain crystals and the softness of other crystals has been found in the fact that a survey of atomic structure seems to point to the former having atoms with electrons common to more than one atom while this is not the case in the soft crystals. In metal crystal atoms some of the electrons are probably not bound permanently to any atom but are free to wander; this may have a bearing on the ductility and malleability of metals in general.

A beginning has already been made in the direction of a practical utilization of what is still a rather delicate scientific technique. This beginning consists in the study of the effects of rolling and aging on metal plates and crystal formation has been very definitely detected in both cases. Here is a field where the metallurgist who knows the practical problems and the physicist who has the experience in this new field of X-ray photography might well get together with the

object of determining whether one of the world's most important industries may not greatly benefit by employing X-ray photography.

Along with the study of crystal structure by means of X-rays there has gone experimentation in the nature of the "characteristic" X-rays with the aid of crystals built up on "space lattices" whose dimensions are approximately known. From this there has resulted a knowledge of the wave lengths of the "characteristic" radiations emitted by the various chemical elements. Nearly all of the chemical elements may be caused to emit "characteristic" X-rays if these elements are used as targets in X-ray bulbs under suitable working conditions. Each of these "characteristic" radiations consists in general of rays of several different wave lengths and many of the elements emit more than one series of radiations, each of which consists of radiations of several different wave lengths. These "characteristic" X-radiations from the various elements are quite similar to the "spectra" of elements in the visible and ultra-violet regions of light, only fortunately they are far simpler than the visible spectra of even the simplest chemical elements.

For more than fifty years physicists and chemists have been endeavoring to bring some sort of order out of the apparent chaos of the spectra of the simplest of the chemical elements—the element of the smallest atomic weight, hydrogen. In the case of hydrogen in the visible and ultra-violet spectra a certain number of the spectrum lines form an ordered series whose position in the spectrum may be calculated from a formula which has been recently derived by N. Bohr on certain assumptions as to how an atom emits energy in the form of light. This formula contains known electric quantities which characterize the electrons and "nucleus" out of which the atom is now supposed to be built up, and it also contains other quantities, among which is the mass of the atom, which are also fairly well known. It is found that this same formula predicts accurately the wave length of the shortest wave which any one of the elements is able to emit as "characteristic" X-radiation, and this prediction is in complete agreement with experiment. This very significant result is taken to mean that the length of the shortest light wave which any atom may emit depends only on the magnitude of the electric charge of the nucleus of the atom.

A still more striking indication that in the wave length of the "characteristic" X-rays emitted by the various chemical elements we have a simple indication of the atomic structure of the element is furnished by the work of Moseley in 1913 and 1914. The discovery made by this brilliant young English physicist, who a few months later was killed in action, ranks among the great fundamental discoveries which profoundly affect human thought and turn it into new channels.

Moseley obtained experimentally the "characteristic" X-ray spectra of nearly all of the chemical elements and found that in general the heavier the atom of the element, the shorter is the wave length of the "characteristic" X-radiation which it emits. While this was in general true he found that there was no simple numerical relation between wave length and atomic weight, but that there was an extremely simple relation between wave length and what is known as the "Atomic Number" of an element. The atomic weight of an element indicates how many times heavier than the atom of hydrogen the atom of the element is, while the atomic number of an element is its *order* in the periodic table of chemical elements. This atomic number which is thus brought into such prominence by Moseley's results, must be more than a mere number—it must represent some fundamental attribute of the atom.

Several independent lines of investigation all point to the same conclusions, viz., that the constitution of the atom may be somewhat similar to that of a solar system—to consist of a nucleus (sun) with electrons revolving in orbits (planets). The nucleus is electrically charged positively and the electrons are negatively charged. Some of these electrons revolve around the nucleus on outlying orbits and some are imbedded in the nucleus or are on orbits very close to the nucleus. The electric charge of the nucleus is that of the nucleus proper diminished by the amount of the negative charge of those electrons which lie close to the center, and thus the number of the so-called orbit electrons which rotate on the outer orbits is equal to the net residual positive nuclear charge. This nuclear charge must be a very fundamental attribute of the atom for on it depends not only the inner constitution of the nucleus but also the number of the orbit electrons. It is thought that the constitution of the nucleus directly determines the mass of the atom and its radio-active properties, while the chemical and optical properties are determined by the number and arrangement of the orbit electrons and thus depend only indirectly on the constitution of the nucleus. According to the modern theory of the constitution of the atom, the nuclear charge of an atom is given by the atomic number of the element. This amounts to saying that as we ascend the periodic table of the chemical elements from hydrogen (the lightest element) to the heavy elements, gold, uranium, etc., each atom differs from the one below it in the table merely by having one more unit of nuclear charge and one more orbit electron. On this view the nuclear charge of hydrogen is one—it has one orbit electron, and its atomic weight is one.

All other chemical elements have nuclei made up of hydrogen nuclei sufficient in number to give the required atomic weight. These nuclei have close-lying electrons sufficient in number to bring the net positive charge of the nucleus to be numerically equal to the atomic number for the element; in addition there are the remaining orbit electrons and these are also equal in number to the atomic number of the element.

The question naturally arises as to why the atomic weights of *all* the chemical elements are not whole numbers if each is made up of a whole number of hydrogen nuclei. The answer which the new theory of atomic structure gives is that two elements may have the same nuclear charge but different atomic weight and be quite inseparable from each other by ordinary chemical means—these are called isotopes. Now a substance like chlorine, whose atomic weight is 35.5, is supposed to consist of two isotopes, one consisting of 35 hydrogen nuclei with 18 inner electrons, and the other of 37 hydrogen nuclei with 20 inner electrons. Each of these isotopes would have a nuclear charge of 17 since $35 - 18 = 17$ and $37 - 20 = 17$. If any quantity of chlorine large enough to allow of experimentation were to consist of three parts of the first isotope and one part of the second isotope, it would actually have the atomic weight which chlorine is found to have (35.5), because $\frac{3 \times 35 + 1 \times 37}{4} = 35.5$ A well-known case of the existence of isotopes (elements sufficiently similar to have the same atomic number but differing slightly in atomic weight) is that of ordinary lead and the lead which results from the atomic disintegration of radium. The most recent experimental work goes to show that many of the elements which have atomic weights which are not whole numbers actually do consist of isotopes which themselves have atomic weights which are exact integers, and so the new theory seems to promise the removal of what has long been an objection to the older atomic theory: that there was no reasonable explanation for the existence of the atomic weights actually found.

Some progress has been made in estimating between limits the actual size of the atoms. The results can be appreciated by imagining a magnification such that an inch appears equal to the distance from the earth to the sun, then an atom similarly magnified would have the nucleus not more than two feet in diameter and the furthermost orbit electrons would be about 3,300 feet and the innermost about 330 feet from the nucleus. The actual size of the atom would probably be smaller than this though not smaller than one-fifteenth of this estimate.

The question as to the constitution of the atom is by no means answered at he present time, but a very encouraging beginning has been made. At least one great step in advance

has been taken in the recognition of the importance of the atomic number of the elements and in the now universal belief that all the chemical elements are built up of the same fundamental units, the hydrogen nucleus and the electron.

The possibilities which such a theory of the constitution of matter contain for physics and chemistry and their utilization for the welfare of mankind are practically unlimited. Who shall say what transformation from the useless to the useful may not be possible if each is built up of the same ingredients? It is not so long ago that the synthesis of useful organic molecular compounds from less useful compounds of the same ingredients was only a theoretical possibility in the minds of a few searchers after scientific truth, and yet but recently a nation tried to fight the whole world on synthetic substitutes for the raw materials it could not get. It does not of course follow that we shall be able to synthesize the atom as it has been possible to synthetize the molecule, but it is well that research so promising as that on the constitution of the atom should be supported and encouraged in every way possible, for atomic synthesis or atomic disintegration will not be attained by haphazard experimentation but only by systematic study.

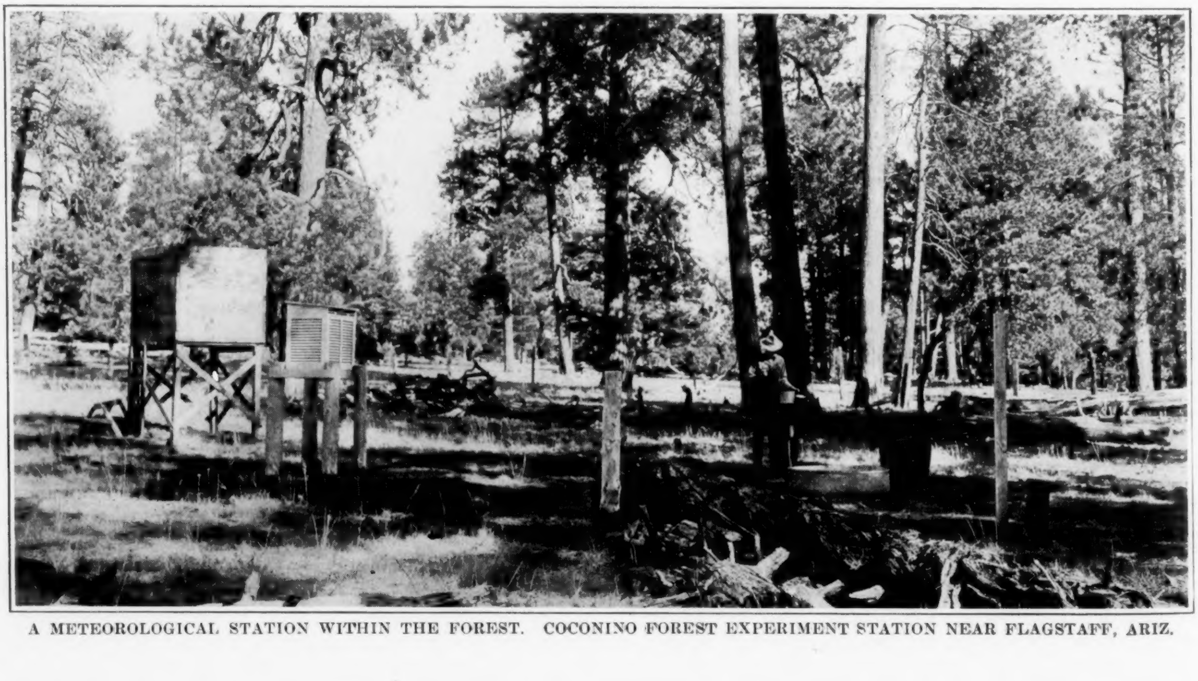
The National Research Council, recognizing the great importance of fundamental research in those branches of physics, such as X-ray spectra, which show such great promise of throwing light on the subject of atomic structure, has organized committees which have met frequently to discuss the outstanding problems and to prepare reports which it is hoped will stimulate interest both in the support and the prosecution of research work in these lines.

RESEARCH—AN AID TO FOREST PERPETUATION

THE growth of forest research in North America has been phenomenal. Barely 20 years ago there were no foresters trained in American schools. Today there are approximately 1,500 trained foresters, graduates of technical schools of high standing, many of whom are devoting their efforts to forest research. Aside from the Federal departments of Canada, Newfoundland, and the United States, there are now from 40 to 50 State, provincial, college, and corporate organizations engaged in the study of problems in forestry and related subjects. The inventory of North American forest research, just published as a bulletin of the National Research Council, lists some 520 investigative projects in forestry. Such a growth in forest research has not been fostered artificially by generous Government or State appropriations. It is to a large extent a spontaneous growth brought about by the needs of the time.

To appreciate the situation one needs only to visualize for a moment the intimate connection which exists between modern civilization and the use of wood. From the cradle to the grave we depend upon wood. We sleep in wooden beds and walk about on wooden floors of our wooden homes. We wash ourselves with soap made with rosin, a product from wood, put on our hose manufactured from wood fiber, and step into our leather shoes cured by tannin extracted from wood. We sit down to breakfast upon a wooden chair in front of a wooden table, read the daily news from a paper made of wood fiber and printed with ink manufactured from a forest product and received over telegraph lines supported by wooden poles. If we are sufficiently prosperous we may go to our office in an automobile with wheels containing wooden spokes and finally settle in our office surrounded by wooden trimmings and furniture, and dig into the daily letters and reports made of wood pulp. We still travel largely in wooden railroad cars over tracks supported by wooden cross-ties. The commodities which form the necessities of life are delivered to us in containers, some of wood and some of fiber, but practically all of forest products. About one-fifth of the 276,000 manufacturing plants which serve our needs use wood in one form or another.

As long as our timber supply was ample and could be easily procured by the wood-using industries at a low cost, there was not much thought of conserving either the forests or eliminating waste in the manufacture of forest products. Conditions, however, have now radically changed. The United States which a few decades ago was the second country in the world as regards the forest area and ranked first in amount of saw timber produced, has increasing difficulties in providing enough raw materials for the existing lumber and wood-using industries. The 820 million acres of virgin forests of this country have now shrunk to one-sixth of that area. There remain now only 137 million acres of virgin forest. The total forest area, including culled, burned, and cut-over areas, still aggregate some 463 million acres. Of this, however, about 80 million acres have been so severely cut and burned as to become an unproductive waste and the remainder is in second growth, more than half of which is below saw timber size and is of relatively inferior quality. The remaining merchantable



A METEOROLOGICAL STATION WITHIN THE FOREST. COCONINO FOREST EXPERIMENT STATION NEAR FLAGSTAFF, ARIZ.

A PLOW AND TRENCHER USED IN THE PLANTING OPERATIONS

HOW THE SAME LAND LOOKED ONE YEAR AFTER PLANTING

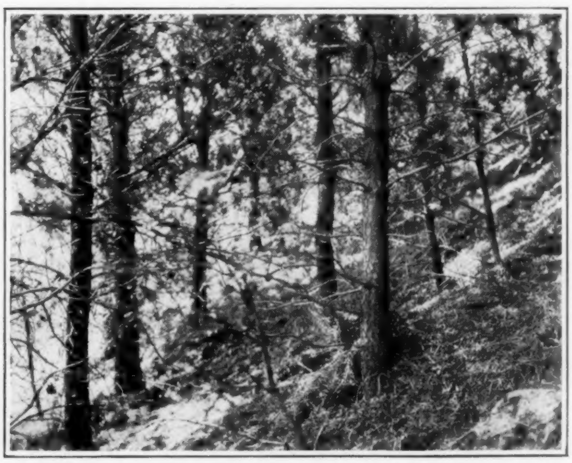
virgin forests are so distributed as to greatly reduce their national utility. While the bulk of the population and manufacturing industries of the United States are still east of the Great Plains, our remaining virgin forests are on the Pacific Coast. This involves long hauls and consequently high prices to the industries depending upon wood.

There is now consumed or destroyed annually in the United States 56 billion board feet of material of saw timber size. Our depleted forests are growing less than one-fourth of this amount. The United States is not only cutting heavily into its remaining virgin forest every year but is also using up the smaller material upon which the future supply of saw-timber depends much more rapidly than it is being replaced. The scarcity of high grade oak, poplar, ash, hickory, walnut, and other standard woods, is now placing many American industries in a critical condition. The bulk of the building lumber and structural timbers used in the Eastern and Central States during the last 15 years was grown in the pine forests of the South. The virgin pine forests of the South Atlantic and Gulf States have now been reduced to nearly one-sixth of their original stand. The production of yellow pine lumber is now falling off and within ten years will probably not exceed the requirements of the Southern States themselves. Since 1909 the country has ceased being self-supporting in newsprint paper and now imports two-thirds of the pulp, pulp wood or newsprint which we require. In 1919 the production of turpentine and rosin had fallen off 50 per cent. Within ten years the United State will lose its commanding position in the world's market for these products and may in time be unable to supply its domestic requirements.

As the timber supply has dwindled, the prices, due to the increasing scarcity and long distance hauls, have steadily gone up. To meet the situation there is need for (1) a change in our present methods of handling the remaining virgin timberlands, so as to prevent their devastation; (2) an increase in the forest productivity of the cut-over or idle land not suitable for agriculture, and (3) the elimination of waste in the handling of the raw material from the log to the finished product. The first two cannot be accomplished without some legislative measures by the Government and States, as it is doubtful if private initiative alone can overcome the economic difficulties in the way of better handling of timber lands. The latter is largely a better knowledge of the product and can be safely left to the self-interest of the industries. All three measures, however, if they are to be effective, must be based on accurate knowledge of the life of the forest, the best means of its perpetuation, and the properties of wood. The whole present agitation for a National Forest program in the last resort must rest on the work of the men of science and the solution of such problems as the best method of converting idle land into productive timber land, methods of cutting which will secure either regrowth of the valuable species or the utilization of inferior species in place of the more valuable kinds whose supply is becoming exhausted, and general improvement in the technical processes of converting wood into other forest products or increasing the yield of by-products from wood.

It is largely under the pressure of the economic necessity of finding a remedy for the growing area of idle forest land that investigations into the possibility of converting it into productive land were undertaken by many States and some associations, as for instance, the Southern Pine Association. The Southern Pine Association has recently contributed $10,000 to the National Research Council to investigate the possibilities of cut-over pine land for timber production. This work is now in charge of a Forestry Committee of the Council and is well under way.

The Federal Government in its timber operations on the National Forests is trying to solve, through several forest experiment stations in the West, the problems of perpetuation of the forest after cutting by natural means and by planting areas destroyed by fire which cannot be brought back into productivity by natural seeding from the older trees. Some of the wood-using industries, although not carrying on forest investigations by themselves, are contributing to some extent and are keenly interested in the work of the Forest Products



TWENTY-FIVE YEARS LATER. A TYPICAL FOREST GROUND COVER ESTABLISHED

Laboratory at Madison, which is solving the many problems of wood utilization, prolonging the life of the material by preservative treatment, increasing the sources of the available products, and discovering new substitutes for valuable kinds which can now be obtained only with great difficulty and at high prices. Forest research, although still young in this country, has already proved its effectiveness. A few examples may be cited as an illustration. Thus the discovery of the fact that the seed of western white pine, the most valuable species of our western forests, has a tendency to lie over in the duff for a number of years and germinate after the timber is cut off and the ground is exposed to heat and sun, has resulted in modifying the timber cutting on the National Forests. Instead of leaving 25 per cent of the total stand as a means of securing natural reproduction, the amount of timber left now is only 10 per cent. This is left more as an insurance against subsequent fires than as a means for reseeding the cut-over land which is now dependent upon the seed stored in the ground. The reduction of 15 per cent in the amount of standing timber, which has an average stand of about 25,000 board feet to the acre, is nearly 4,000 board feet, or at the minimum price of $4 per thousand is a net gain of $16 per acre. There are about 850,000 acres of western white pine land which when cut over under the new method of marking timber, would represent a gain of nearly $14,000,000 to the Government, as against the old method of cutting.

For years a greater part of western Nebraska was known as the Great American Desert. Aside from a few ranches along the river valleys and low-lying land close to lakes, the land was used for the grazing of long-horned cattle that were trailed across the country from Texas and then sold in the fall at Missouri River markets. Grazing, however, was so poor that the business proved unprofitable and 20 years ago there was very little use made of the sandhills. In 1902, 206,000 acres of this desert were set aside by presidential proclamation for raising timber. In 1903 the Government established its first plantation. After many failures in the struggle with adverse climatic conditions, the Forest Service has developed a successful method of converting the Nebraska bad lands into thriving plantations and today there are about 3,500 acres which have been planted successfully at a cost of about $16 per acre. The weary traveler, passing through the uninteresting sandhill region in Nebraska on the Billings Branch of the Burlington Railroad, is now astonished after hours of gazing at bare sandhills, to come suddenly upon green hills covered with evergreen trees. A desert has been converted into a forest which is now becoming a game refuge and soon will be the playground for people in the prairie country and a source of timber. This has been accomplished only through persistent research in the face of many discouraging conditions.

There are very few nowadays who will deny the protective value of forest cover on watersheds for irrigation purposes, water power development, use of water for domestic purposes, and stream regulation and conservation in general. One of the main purposes for which National Forests have been used in the West was to secure favorable conditions of water flow. It has been estimated that the service which the National Forests perform in the conservation of water for irrigation alone is worth *two and one-half billion dollars annually.* To detemine accurately the effect which forest cover has upon the behavior of streams for the better management of protective mountain forests, the Forest Service in 1909 undertook an experiment at Wagon Wheel Gap, Colo. Two small watersheds were selected and carefully surveyed as to cover, topography, and geological formation. Dams were built at the mouths of the watersheds where automatic recording instruments registered the amount of flow throughout the entire year—summer and winter. A net of meteorological observations was established in coöperation with the United States Weather Bureau on both watersheds covering precipitation, temperature of the air, moisture of the soil and air, evaporation and snow depth. For 10 years no change in the forest cover was made, but last year one of the watersheds was denuded except for a strip of trees along the stream itself. Observations are now to be conducted for a series of years to bring out the effect of forest denudation. As all other conditions were made equal any change in the flow of the stream from the forested and deforested watershed must be due to the elimination of the forest cover on one of the watersheds.

There is only one other experiment of this kind in the world and that is in the Swiss Alps not far from Zurich. The American experiment, however, is more thorough and the results should be more conclusive, as in the Swiss experiment no water measurements are taken during the winter months and the two watersheds selected differed from the very beginning in the density of their forest cover and no denudation of any of the watersheds has taken place. The results of the experiment may be expected within the next 5 or 10 years, as it is desired to carry the observations over a cycle of dry and wet years and should settle forever the value of forest cover in stream control and furnish an accurate basis of determining that value in any future engineering projects.

In the field of wood utilization the results so far secured are no less striking. In pulp and paper investigations about

MILLIONS OF DOUGLAS FIR SEEDLINGS READY FOR PLANTING ON BURNED AND DEVASTATED LAND

THE KIND OF DEVASTATED AND BURNED LAND WHICH IS BEING PLANTED

13 species of American timber which heretofore were not known to be suitable for the manufacture of ground wood pulp have proved to be adapted for such use. In the manufacture of soda pulp the time of cooking, as a result of experimentation, has been reduced by 20 to 60 per cent, thereby making possible an increased production with existing plants of from about 50 to 100 per cent. Laboratory investigations in hardwood distillation have shown that with no increase in the cost of equipment or operation of a commercial plant the yield of wood alcohol and acetate of lime may be increased approximately 30 per cent and 15 per cent, respectively.

The building and construction trade uses annually about 5½ billion feet of timber. This material is worth roughly $200,000,000. Investigations at the Forest Products Laboratory on the mechanical properties of American woods have shown that 20 per cent increases in the allowable strength stresses of structural timbers are permissible. This means the use of smaller timbers with subsequent saving of raw material and possible economy in the cost of about $40,000,000 annually. If results are actually applied to only 10 per cent of such material the annual saving would still be equal to about $4,000,000. Improved methods of turpentining developed by the research workers in forestry resulted in increased yields and less injury to timber with a net saving aggregating $4,000,000 a year. Economies in this direction are unlimited.

Our present consumption of lumber is around 40 billion board feet. This represents probably not less than 75 billion feet of standing timber in the woods. There is an enormous waste between the tree and the finished product. It is roughly estimated that by better methods of utilization based on scientific investigations a saving of over 10 billion feet is possible. Ten billion feet of ripe timber saved each year means a saving of one year's supply every four years. It means prolonging by 25 per cent the remaining timber supply. Merely to indicate the possible economies in the use of wood a few illustrations may be mentioned. The railroad and electric lines in this country use about 120,000,000 wooden ties a year. Of this about 28 per cent are treated with some preservative. The average life of a railroad tie properly treated is 15 years, of an untreated tie about 7½ years. If all ties were treated there would be an annual saving on railroad ties alone amounting to from 1½ to 2 billion board feet a year. If in addition to the ties, poles, posts, mine props, shingles, and other lumber used under conditions subjected to decay were treated, the annual saving would be increased to some 6 billion board feet.

The best utilization thus far accomplished under chemical processes in the manufacture of paper is 45 per cent of the wood substitute. That means that for every cord of wood pulped, some 55 per cent of the original weight of the wood is lost, and for the total annual consumption over 2,000,000 cords a year. Now by proper methods of storing, preventing shrinkage in the weight of wood and loss through decay, a saving of some 600,000 tons of pulpwood might be effected. It is believed that there is an annual loss of one billion feet in the drying of lumber. By proper methods of kiln drying this loss could be cut in two.

Important as are the results already accomplished by forest research in this country, they appear extremely small as compared with the enormous size of the industry depending upon wood and the vital interests of the country as a whole. The lumber and wood-using industries are among the greatest and most important manufacturing industrial developments of the country. Of the various industries they rank second in invested capital, first in labor employed, and second in annual value of products. Yet the total appropriation for forest research in this country barely exceeds $600,000 a year, covering all the activities, Government, State, college, and individual. This is less than one-hundredth of one per cent. Compared with the expenditures of research of such industries as the steel, chemical, telephone, and photographic industries, etc., the wood-using industries of this country have not begun to realize the possibilities through research.

Notes on Science in America

Abstracts of Current Literature

Prepared by Edward Gleason Spaulding, Professor of Philosophy, Princeton University

AN ANALYSIS OF EARTHQUAKES IN PANAMA

MR. R. Z. KIRKPATRICK, Chief Hydrographer for the Panama Canal, communicates to the *Bulletin* for the Seismological Society of America for September, 1920, an analysis of the earthquakes observed in Panama up to January 1st, 1920. Mr. Kirkpatrick states that records of seismic disturbances on the Isthmus prior to American occupation are meager and conflicting. The best available records show seventeen shocks prior to 1900 and eleven shocks between 1900 and 1904, one of which can be classed as destructive—that of September 7, 1882.

No record of shocks is available between 1904 and 1906, but from 1906 to 1908 inclusive, such shocks as were sufficiently intense were recorded by an old French seismoscope. During these three years twenty-eight disturbances were recorded in this manner.

In December, 1908, two 100-K and two 25-K horizontal pendulum Bosch-Omori seismographs, with damping mediums, were installed at Ancon and continuous seismological records have been kept since that time.

Four hundred and twenty-nine seismic tremors have been recorded from that time up to the close of the year 1919, some being of nearby origin and some faint tremors from remote disturbances. *Thirty-two per cent* of these tremors have had an origin less than *two hundred miles* distant from the observing station, *twenty-eight per cent* have been distant between *two hundred and five hundred miles*, *twelve per cent* have been distant between *five hundred and one thousand miles* and *fourteen per cent* have been distant *over one thousand miles*. The remaining *fourteen per cent* have been those slight tremors that were not sufficiently well marked to admit of calculation. The majority of these give indications, however, of being of remote origin.

The most important disturbances, so far as the Isthmus and Canal Works are concerned, are those tremors which originated less than two hundred miles away. These have ranged in distance from eleven to two hundred miles with the majority between one hundred and one hundred and fifty miles.

Of those less than one hundred miles away, it may be said in general, that they are usually perceptible even if they are but slight tremors.

Those tremors with an origin between one hundred and two hundred miles are seldom perceptible unless more pronounced than those of nearer origin; nearly all the more violent disturbances experienced in the Canal Zone have had their origin a little more than one hundred miles distant.

The author quotes Prof. Harry Fielding Reid and Prof. Stephen Taber as saying: "Where earthquakes have occurred frequently in the past they may be expected to occur frequently in the future. This rule, however, cannot be applied to a given district with any degree of certainty, unless there is a history of earthquake frequency extending back through a period of several hundred years.

"All severe earthquakes are followed by aftershocks which decrease gradually, though not uniformly, in frequency and

intensity. In some instances they continue for several years, while in others they die out rapidly. Some of the after shocks may be due to the extension of the displacement which caused the initial disturbance, others to the relief of local stresses which result from, or are increased by, the earlier movements."

In conclusion Mr. Kirkpatrick says: "There is an abrupt break or fault line in the ocean floor extending all along the Pacific Coast, and at no great distance from the shore line. It is probable that this fault line, in the majority of cases, is often the seat of the seismic disturbances recorded at Balboa Heights. It also seems that the adjustment which takes place along this fault occurs at different localities, at different periods and that the movement is more active to the southwest, west, and northwest of the Canal Zone; at least, at the present time."

ACTION OF X-RAYS UPON FERTILIZED FROG'S OVA

IN *Science* for September 3rd, 1920, Dr. W. M. Baldwin of the Union University Medical College, gives an account of investigations, interesting and possibly significant, to determine the action of X-ray energy upon the fertilized frogs' ovum, through raying the entire egg at different developmental stages.

The eggs were permitted to develop in the ponds where they were laid until the proper stage of development had been reached, whereupon they were brought immediately into the laboratory and rayed, development being permitted to progress in glass jars. Of the 300 eggs used for the experiment, upward of fifty were sectioned serially. The embryos were fixed in formalin after Schultze's method at varying intervals after raying. None, however, was permitted to develop to the time of metamorphosis. In all of the experiments the distance from the target to the eggs and the per-second energy output of the tube were constant as was also the time of exposure. The tube carried a current strength of 50 milliamperes at 50 kv. A dosage of 100 mam. was given to each group of from twenty to twenty-five eggs. These were placed 17.5 cm. from the target. The different groups represented approximately every developmental stage from the two-cell to the period of the closure of the neural tube. No attempt was made to orient the eggs with reference to the tube so that the animal pole or the vegetable pole or right side or left side of the embryos should be uppermost.

The developed embryos were found to be identical in every gross and microscopic detail to those produced by raying the whole ovum at the two-cell stage as described by the same author in the *Anatomical Record* of November, 1919. This uniformity of results, irrespective of the stage rayed, is the most striking feature of the experiment. Sections of these embryos resemble in every histological detail those produced by the former method, and could serve very well to illustrate the results of that investigation. The experiment represents, therefore, still another method by means of which a standardized, defective, morphologic condition may be produced.

Owing chiefly to our present lack of knowledge of the association of chemical formula with morphologic structure in the ovum, a completely satisfactory explanation of this phenomenon cannot be given.

The factors concerned fall into two natural categories, one embryological and the other chemical or physical. Granting the presence of a series of chemical ontogenetic modifications preceding the known morphologic features of cell differentiation, it is not impossible that one and the same molecule whether falling in the category of proanlagen nutritive or enzymatic substance might, regardless of the oxidative or reductive changes incident to its elaboration, show the same capacity of absorption of energy in the two-cell stage as in the gastrula or neural-plate stages. A constant and uniform alteration of this molecule might be assumed to lead to a correspondingly constant and uniform embryological result. To Dr. Baldwin, however, the hypothesis that seems most probable is that certain protoplasmic substances maintain a constant structure, both physical and chemical, during the early stages of ontogeny. It argues equally well, he thinks, for the results produced whether we determine the nature of this constant content to be nutritive or enzyme, since it is conceivable that the deprivation of the enzymes of the substances out of which the morphological structures of differentiation are formed would lead to the same developmental result as the inhibitive effect of energy acting upon the ferments themselves. The presence of retardation effects is well attested both by this and by the earlier experiment and might well be accounted for on these grounds.

It is significant that there is an absence of evidence pointing toward the destruction either of protoplasmic or of nuclear material. A more severe degree of injury brought about by the use of a greater amount of energy was evident through the presence of both protoplasmic and nuclear detritus. Furthermore, it must be pointed out that the change brought about is not incompatible with the vitality of the cells. There appears to have been suspended apparently the function of but one physiological factor of cell development, that of differentiation, unattended by any morphologic indication of destruction. The precise nature and location of this alteration, if morphologic, cannot, however, at present be identified.

THE ORIGIN OF TWINS

LIGHT was thrown on the origin of twins by Dr. Charles B. Davenport, director of the Carnegie Institution station for experimental evolution, in a paper read before the recent annual meeting of the Eugenics Research Association.

About one per cent of the population consists of twins. It is generally known that heredity has an important part in the appearance of twins, as they tend to run in families. Dr. Davenport stated that about 11 per cent of the twins' relatives on the maternal side will be found to be twins. On the other hand, the percentage of twins in the paternal ancestry is about the same, which leads to the inevitable conclusion that the father has some part in the production of the twins as well as the mother.

Most twins are the result of the fertilization of two ova, and about 10 per cent of all ovulations are double ovulations, according to Dr. Davenport. If all these ova were fertilized and developed, there would be 10 per cent of twins in the population instead of 1 per cent. There is, therefore, a disappearance of 9 per cent of double ovulations to be accounted for, and Dr. Davenport believes that in these cases one of the ova after fertilization fails to develop normally for some reason. In many cases this may be due to the fact that the spermatazoön introduces some inherited traits that, when combined with those of the ovum, have a lethal effect and prevent development. This is a well-known phenomenon in lower animals. About four-fifths of all the twins are the result of the fertilization of two ova. In about one-fifth of all the twin births, however, the two individuals are apparently formed by two buds from a single ovum. These are the so-called identical twins and are always of the same sex, whereas ordinary twins have an equal chance to be of the same sex or of opposite sexes.—From *Social Hygiene Bulletin*, Sept., 1920.

STANDARDIZING STATE EUGENIC EFFORT

SINCE the rise of the science of eugenics many States have taken measures in the direction of applying the results of that science. There is need, however, of discovering standards of State eugenic effort and applying these to the varying conditions encountered in individual States.

A promising attempt along this line of standardization is offered by Chester L. Carlisle, until recently director of the Bureau of Analysis and Investigation in the Department of Charities and Correction for the State of New York. Bulletin No. 13, entitled "The Problem of the Mental Defective and Delinquent," issued by this Bureau, outlines a comprehensive program for the care and treatment of these classes of our

population. His plan gives as chief objectives in this work: "(1) The greatest good of the individual case; (2) the highest type of care, treatment and research, in order that latent capacity may be developed; (3) the conservation of the social possibilities of persons who otherwise would become economic wastage; (4) the protection of society from undesirables." That Dr. Carlisle approaches these problems from the biologic and genetic side will be gathered from the following citations: "If conduct is to be considered in a broad way as the final resultant of mental actions carried out through our physical agencies, then we begin to understand how an individual showing anti-social trends as a result of inadequate reactions to mental conflicts becomes delinquent. The forces of heredity have been widened in their significance by the investigations of later years. We no longer think of the inheritance of similar characteristics as such, but rather that the presence or absence of specific determiners in the germplasm leads to the development of individuals destined to produce certain types of reaction in symptom-behavior. Through the inter-relationship of all these heritable factors which enter into the personality make-up of any unit of any certain family, one sees how by changing the number and value of the determiners, a certain family tree may show one or all of the various types of mental defect or mental disorder, either in the sense of quantitative intelligence defect, affective imbalance, epilepsy, or the more pronounced make-up deviations expressed as a constitutional type of psychosis, or in delinquence of dependency (inadequate economic reactions)." Concerning the duty of the State toward those whose ability is below the average, he says: "In a sense the State is not particularly interested in the individual, even though he may seem mentally deficient, provided his affective reactions are stable and his conduct represents constructive economic efficiency, even though in a humble manner. So long as he does not, through conspicuously bad mating, increase the virulence of his strain in the body politic, and develops no other attitude definitely anti-social, his mental defect is of academic interest only. Such stable types of mild mental defectives are found doing the humble work of the world and have a distinct value in the social structure. Nevertheless, the State has a right to know, and it is its duty to ascertain the exact number of all such types as far as possible, in order that it may record their whereabouts and curb the possibilities of their developing by indiscriminate mating, geographical foci of mental defect. To this end there is the pressing need of a system of State-wide registration of defectives and delinquents."

THE REFRACTION OF LIGHT IN PLANT TISSUES

IN *the Bulletin of the Torry Botanical Club* for June, 1920, Mr. Forest B. H. Brown of Yale University publishes an important article on the refraction of light in plant tissues. In the introduction to his article Mr. Brown points out that the laws of refraction have an interest in microscopy, not merely in connection with the definition of anatomical details, but also in the determination of the chemical or physical qualities of any part or product of the cell. Such laws are of universal application, have the advantage of great precision, and serve to differentiate many characters not readily brought out by stains or chemical reagents. Furthermore, a knowledge of the refractive properties of the various tissues is indispensable if one is to obtain the clearest definition of tissue outlines by aid of the microscope. Current methods, however, go little further than listing the indices of refraction of media in which tissues may be mounted, all of which have little significance in anatomical work unless the index of refraction of the tissue substances is also given. Inasmuch as many, if not most, of the ultra-microscopic characters of cell membranes are to a greater or less extent associated with the refractive powers of these membranes, the laws of refraction have their special application in the investigation of the physical or chemical composition as well as in the anatomical characters of cell membranes. Such laws, therefore, in their application to plant tissues, come well within the scope of botanical research, and, as such, open a wide field for investigation, particularly when more than ordinary precision is required.

The methods by which it is possible to determine the refraction of an object (under the microscope) depend on the use of mounting media of known refractive powers. With a gradient series of such media, the index of refraction of an object may be measured with accuracy to the second decimal place.

To measure the refraction of an object microscopically a gradient series of refractive liquids must first be prepared. For plant tissues in the dry condition, a series of twenty liquids differing from each other in refraction by about .005 and ranging from 1.499 to 1.598 was found generally satisfactory. Either aqueous solutions or oils may be used in making up such a series, both water and oil possessing certain advantages over the alternative solvent.

A gradient series of refractive liquids may be prepared by mixing a liquid of high refraction with one of low refraction.

In preparing tissues for the measurement of their refraction the following schedule was adopted:

1. Cut as many sections, 10-40 μ thick as there are refractive liquids in the series, and wash in water for 10 minutes or longer.
2. Transfer each section to a separate slide and cover with a glass slip.
3. Dry for at least 15 minutes at 100°C. An electric oven is useful for this purpose.
4. Remove the slides one at a time from the oven and mount each section in a different refractive liquid of the series. The samples of tissues are then ready for microscopic examination.

In summary of his results obtained by these methods Mr. Brown says:

The refractive index of the material of which any given cell-membrane or cell-content is composed is fairly constant with uniform conditions of temperature; but during the growth of a tissue the refraction of its constituent materials may change enormously. Such changes in refraction are evidently associated with corresponding changes in the chemical composition.

The indices of refraction of the various membranes and other elements of which mature plant tissues are composed, differ greatly from one another, and a given tissue complex will rarely if ever have a single refractive index. A fair average, however, would be about 1.53 or .01 above that of Canada balsam.

Most tissues readily absorb water and other refractive liquids, in differing amount according to the hygroscopic qualities of the tissue. This causes the refraction of the mass (tissue substance-imbibition liquid) to deviate correspondingly from that of the tissue substance. The refractive index of the membrane mass is highly sensitive to physical changes of this kind.

The laws of refraction have their special application to the investigation of both the anatomical characters and the physical and chemical properties of plant tissues.

With average sections, clearer definition is obtained when the index of refraction of the medium is below, rather than above, that of the tissue substance. A difference of at least .05 between tissue mass and the medium in which it is mounted is desirable to obtain clear definition of small perforations and similar minute details, and highly refractive media such as styrax, tolu, and quinidine bring out such details with the greatest possible clearness; in moderately thin sections, a difference of .005 is sufficient for the definition of general outlines, and may give clearer definition for general features than a greater difference in refraction.

In selecting a medium, to obtain a given difference in refraction between it and the tissue mass, due allowance must be made for the deviation in refraction brought about by the imbibition of liquid by the tissue.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

WORK IN CONNECTION WITH LENGTH MEASUREMENTS

THE section devoted to linear measurements is engaged in a greater variety of work than would ordinarily be supposed. This is perhaps due to the fact that measurements of length are used in practically every kind of work and form the basis of many of the investigations necessary in order to establish other kinds of standards.

Two examples may serve to show the wide field covered by this phase of the weights and measures work of the Bureau. The size of the mesh is an important consideration in the use of certain kinds of sieves, such as those used for determining the fineness of Portland cement. Many of these are examined by the Bureau to determine whether the number of wires per inch is accurate enough to come within the required tolerance. Several methods for counting the number of wires are in use, one being by means of an actual count of the wires either viewed with the naked eye or through a microscope.

In the case of sieves of very fine mesh, such direct counting requires considerable time with a large chance for error. The system in use in this case is a very simple and expeditious one. In the case of a 200-mesh sieve, that is, one having 200 wires to the inch, a glass scale is used upon which are ruled exactly 200 lines per inch of length. If this scale is placed over the sieve and the latter illuminated from below, alternate light and dark bands will appear on the scale indicating the number of wires over or under the required mesh possessed by the sieve. These bands are produced by what is known as picket fence interference. Of course, if the sieve has exactly 200 wires to the inch, and if the scale were so placed that each line corresponded to a wire, the light would readily pass through, while with each line opposite a space, darkness would be obtained. The direction in which these light and dark bands move when the scale is moved is an indication of whether the number of wires is over or under that required.

An entirely different line of work is that necessary in the testing of steel and other kinds of tapes, such as ordinarily used by surveyors and engineers in making field measurements. For this work, what is known as the tape tunnel is provided. This is a long, narrow room in which is placed the Bureau's 150-meter comparator and also a bench equipped with long steel bars provided with platinum plugs at certain points to give the graduations in feet and meters. The tapes to be tested are stretched along this bench and compared directly with the bars above mentioned.

The testing of haemacytometers for the Surgeon General's office of the army is an important part of the length measurement work. A great many of these are received each month and are tested by the Bureau to determine whether they are sufficiently accurate.

Upon consideration it will be seen that all these measurements are really referred back to the fundamental length standard in this country, that is, the meter bar kept in the vault at the Bureau, since the working standards of the Bureau are all based upon the national prototype meter and it is these standards that are used in conducting the work described above.

A NOVEL WAY FOR DETERMINING THE AMOUNT OF WEAR OF AUTOMOBILE PARTS

THE Motor Transport Corps of the Army has been conducting a series of experiments to determine the amount of wear occurring in the gears and other moving parts of automobiles, and has recently requested the assistance of the Bureau in connection with this work. As the wear on some parts is very slight, it is extremely hard to determine the amount which has occurred over a comparatively short period of time. The system adopted is a novel one and consists of weighing the parts on the accurate balances of the Bureau before and after the pre-determined length of service. A number of bearings and gears have been accurately weighed and returned to the Motor Transport Corps for assembling in the machine undergoing test. These will be later returned to the Bureau for reweighing, the difference in weight representing, of course, the loss of metal due to wear.

ENCOURAGEMENT OF RESEARCH WORK IN ELECTRO-DEPOSITION

THE art of electroplating is an extremely important one as this process is used in a great many industries. Unfortunately it has not received the scientific attention which its importance warrants and it is only comparatively recently that investigations in this subject have been undertaken. During the month a member of the chemical staff of the Bureau attended the semi-annual convention of the American Electro-Chemical Society at which several papers dealing with electro-deposition were read and discussed. An informal conference was likewise held during the convention and arrangements made for the assignment of one or more graduate students in Ohio State University to research work in connection with electroplating. This work will be carried out in coöperation with the Bureau of Standards and it is believed that the making of other similar arrangements should be encouraged in order to increase the amount of research work in this field and to render the Bureau available in some degree as a clearing house for information on this important subject.

WORK IN CONNECTION WITH NATIONAL PLASTERING CODE

IN compliance with an insistent request from those interested in the plastering industry, the Bureau has undertaken to write a National Plastering Code. It is intended that this code shall contain specifications for all materials used in wall plaster, with complete directions for their use. Results of this work will eventually form the basis of a Bureau publication, which will be in such shape that it can be adopted verbatim by municipal and State legislative bodies, in the preparation of building codes.

The ground which it is proposed to cover has been divided for convenience into the following chapters: 1. Introduction; 2. Preparation for masonry surfaces and specifications for lath; 3. Specifications for plastering materials: 4. Directions for the mixing and application of plaster; 5. Properties of the finished plaster; 6. Renovation and decoration; 7. Miscellaneous: suspended ceilings, corner beads, etc.

To assist the Bureau in this work, there has been called together a conference of representatives of the various industries involved. The personnel of this conference is such as to give established authority to its findings, and is as follows:

MATERIALS' MANUFACTURERS

Portland Cement Association, J. E. Freeman, Chicago; National Brick Manufacturers Association, W. W. Griffiss, Baltimore; Hollow Tile Building Association, C. C. Crockatt, Chicago; Associated Metal Lath Manufacturers, Wharton Clay, Chicago; National Lumber Manufacturers' Association, D. L.

Haigh, New York, and V. G. Marani, Chicago; National Lime Association, L. H. Hart, Washington, and T. B. Shertzer, New York; National Association of Sand and Gravel Producers, E. G. Sutton, Indianapolis.

USERS

Contracting Plasterers International Association, J. J. Earley, Washington; Operative Plasterers and Cement Finishers International Association, J. M. Myles, Philadelphia; Wood, Wire and Metal Lathers International Union, W. J. McSorley, Cleveland.

INDEPENDENT

National Board of Fire Underwriters, I. H. Woolson, New York; Supervising Architect, U. S. Treasury Department, J. W. Ginder, Washington; American Institute of Architects, E. M. Donn, Jr., Washington, and D. K. Boyd, Philadelphia.

BUREAU OF STANDARDS

Cement and Concrete, J. C. Pearson; Fire Resistance, W. A. Hull; Acoustics, E. A. Eckhardt; Lime and Gypsum, W. E. Emley, Chairman.

This conference was organized in January, 1920, and work has been steadily conducted by mail since that time. The first meeting, held at the Bureau on September 14, was called for a final discussion and criticism of Chapters 1 and 2, which had previously been prepared and criticised by mail. Eleven members were present, and six more offered carefully prepared written communications. After a 12-hour session all of Chapter 1 and about three-fourths of Chapter 2 were adopted.

There will probably be another meeting of the conference in December, when sufficient additional material will be ready for attention.

BEARING METALS

EXPERIMENTAL work on determining the compression and hardness values of white metal bearing alloys at temperatures up to 100°C. has been completed. A paper has been prepared entitled "Some Properties of White Metal Bearing Alloys at Elevated Temperatures," a summary of which is as follows: An apparatus is described for determining the yield point and ultimate strength of white metal bearing alloys at temperatures up to 100°C. A new design of heating apparatus is described for determining the Brinell hardness of such metals in the range of temperatures indicated above. The results of compression tests and Brinell hardness tests at temperatures up to 100°C. are given for five typical white metal bearing alloys, including three tin base alloys, one lead base alloy, and one intermediate alloy. These tests showed that the tin base alloys maintain their properties better at elevated temperatures than those containing lead. Results of tests are given which indicate that up to 3 per cent the lead in a high grade babbitt does not affect the yield point or ultimate strength at 25°C. or 75°C. Tests are described which show that the yield point of tin base alloy is not affected by heating for six weeks at about 100°C. but that the yield point is lowered in the lead base alloy by heating for only two weeks at this temperature.

PREPARATION OF MAGNESIUM OXIDE

A VERY satisfactory and economical change has been made in the process of preparing magnesium oxide from epsom salts. The method used commercially to produce magnesia has been successfully applied to the calcination of small charges. The magnesium oxide, practically free from sulphur, is electrically calcined, in large part actually fused in an electric resistance furnace similar to those used for the production of carborundum, that is, the magnesium oxide is packed about a small carbon rod between two large carbon electrodes set in the end of a box-like concrete shell lined with zircite. The electric current first heats the small carbon rod to a temperature which fuses the magnesium oxide with which it is surrounded. This fused magnesium oxide then has greater conductivity and the cross-section of this core of the fused material gradually increases to the end of the run. A run in one small furnace takes about 30 minutes and a fused core of about 15 to 20 pounds of pure magnesium oxide is produced.

FRITS FOR WHITE WARE GLAZES

IN this country white ware glazes are made with the use of a considerable amount of fritted material of which boric acid, feldspar, and whiting are the most important constituents. For the most part these frits are made by the crude and expensive method of firing the saggers in pottery kilns, while in a few plants they are melted in special frit kilns. A special investigation has been undertaken of various mixtures of feldspar, boric acid, and whiting to determine the most satisfactory mixture of these materials for use in white ware frits and also to discover the most economical and efficient method of their manufacture.

FISH SCALING OF GROUND COAT ENAMELS

THE study of the cause and control of fish scaling of enamels has been continued, by the preparation of two series with a total of 14 enamels, in one series the feldspar being high, while in the other the quartz is high. In each series the fluxes are varied in a systematic manner. The results obtained thus far agree with those for gray ware enamels, that is, the constituents which tend to promote or retard fish scaling have the same results in the two types of enamels. Furthermore it was found that there was little tendency to fish scale in three-coat enamels applied to low copper steels which agrees with the results obtained with one-coat enamels. The determinations of the thermal expansion of various types of enamels used for coating sheet steel is being continued.

THE WATERPROOFING OF STONE

IN certain sections where the weather, particularly in the winter, is severe, the waterproofing of stone work is of considerable importance. This is particularly true in the case of monuments and similar structures. As the result of several requests, the Bureau has undertaken a complete investigation of the subject to determine what type of compounds is best adapted to the purpose. Such material should, of course, be colorless and should have no harmful effect upon the surface to which it is applied. Several samples of limestone have been treated with various proprietary compounds and one sample of sandstone has been treated by a paraffin process. It is hoped that some results will be available in the near future.

STUCCO WEATHERING TESTS

SOME further experiments on the durability of stucco under actual weathering conditions have been made during the past month through the coöperation of one of the large producers of magnesite stucco. The east pent house of one of the Bureau's buildings has been coated with two coat work, the work of actually applying the coating being done by an expert sent to Washington by the producer. This should give an ideal condition for testing the durability of magnesite stucco. The base used was a hard, burned, scored Dennison tile set in a 1:3 Portland cement mortar, using about 20 per cent hydrated lime with this to make it easy working. In applying the coats, a chloride solution of 21 Baume was used. First, the walls were thoroughly saturated with the solution, then the first coat applied about one-half inch thick. This was heavily scratched with a special trowel and allowed to set about 24 hours. This was followed by the second coat which was applied with the same thickness and immediately covered by dashing Crown Point feldspar screenings upon it. During the tests a sample of magnesite and chloride was taken for each batch mixed, and contraction and expansion plugs set in various parts of the wall. It is planned to have physical tests made in the laboratory in order that an intelligent study can be made of the action of magnesite under weathering conditions.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

By H. E. Howe, Member of American Chemical Society

RARE SUGARS

SUGAR as the term is usually employed is connected almost wholly with sucrose either derived from sugar cane or sugar beets but there are a number of the rare sugars unknown to the average consumer but highly important to scientific work. Until comparatively recently these rare sugars have been imported but at the present time several American manufacturers are prepared to supply the requirements of scientists, particularly for the detection of certain bacteria. It will be obvious that sugars for these purposes must be of the utmost purity, for the presence of even traces of other kinds of sugar would render them unsatisfactory for the precise use for which they are intended. Their preparation also involves treating large quantities of raw material to make a little refined product.

We complain of the current price of sucrose but dulcitol is a rare sugar for which $375 a pound is asked; manose which is made from the waste of ivory nuts used in button making brings $140 a pound; and xylose made from corn cobs, $120 a pound. Aribinose brings $100 a pound, levulose $80 a pound, and raffinose which sometimes occurs in the manufacture of sugar from beets only $75 a pound. To be sure, these rare sugars are customarily sold in ounce lots.

Another sugar of historical interest is mannite which is prepared from the nutritive gum, manna, familiar in Biblical history. Inulin is prepared from dahlia bulbs.

One of the sugars is of great value in the detection of typhoid. The bacillus thrives upon it as upon no other food stuffs and when present it can, therefore, be readily detected. Cholera is another disease, the germs of which can best be detected by the employment of these rare sugars. The interesting story of how American manufacturers may produce these costly sweets has been set forth in one of the bulletins of the American Chemical Society News Service.

NOVEL REPAIR PROCESS

THE following note is quoted from a recent issue of *Chemical and Metallurgical Engineering*:

"Among the novel repair processes developed by the war is the electrolytic deposition of a thin layer of iron up to one-twelfth of an inch thickness on any simple cylindrical surface of wrought iron or mild or cast steel. Describing the method to the British Institution of Automobile Engineers, B. H. Thomas states that the iron is deposited directly on the surface without any intermediate film of copper, and can be heated to redness without apparent deterioration, can be carbonized or hardened in the ordinary way, can be filed and ground, and takes a high polish. The work being properly done, the adhesion was so strong that the film could not be chipped away from the metal beneath with hammer and chisel. In a heavy repair shop the motor vehicle parts reclaimed in this way included stub axle arms, steering swivel pins, brake and clutch shaft ends, change speed lever shafts, inside of wheel hubs, outside of axles, tubes and universal joint pins. The wearing qualities of the deposit on a high-speed journal do not appear to have been determined. So far the process cannot be used for cast iron or aluminum and its value would be much increased if it could give an adherent coating to such parts as worn gear boxes and ball-race housings."

THE ODOROUS CONSTITUENTS OF APPLES

THE *Journal* of the American Chemical Society publishes the work of F. B. Power and V. K. Chestnut on odorous constituents of apples and the emanation of acetaldehyde from ripe fruit, this being the first definite record with respect to these subjects although a preparation known as "apple oil" consisting entirely of artificial products, has long been in use.

The work has been done at the Bureau of Chemistry, Department of Agriculture, and these facts are determined:

"1. The odorous constituents of apples consist essentially of the amyl esters of formic, acetic, and caproic acids, together with a small amount of the caprylic ester and a considerable proportion of acetaldehyde.

"2. Acetaldehyde is a product of the vital activity of the fruit, and occurs in the exhalation from ripe apples.

"3. In addition to the substances mentioned in paragraph 1, the aqueous distillate from fresh apple parings contains exceedingly small amounts of methyl and ethyl alcohols as well as a little furfurol. As the last-mentioned compound is only produced during the process of distillation, it does not represent an odorous constituent of the fruit.

"4. The essential oil from apples is at ordinary temperatures a yellowish, somewhat viscid liquid, which becomes darker on keeping. When slightly cooled, it forms a concrete mass, due to the separation of small acicular crystals which consist of a paraffin hydrocarbon. It possesses in a high degree the characteristic fragrant odor of fresh apples. Besides the esters mentioned, it contains small amounts of acetaldehyde and furfurol. The yield of oil from the parings of Ben Davis apple was 0.0035 per cent, and that from the more odorous crab-apple 0.0043 per cent, representing 0.0007 and 0.0013 per cent, respectively, of the entire fruit.

"5. Although in chemical literature amyl valerate is generally designated as "apple oil," it is quite certain that this compound has never been found in the apple, and in the recent investigation no evidence could be obtained of its presence. On the other hand, the characteristic, fragrant odor of ripe apples has now been shown to be due to a combination of the substances enumerated above. These substances may exist in varying proportions in the numerous varieties of the fruit, thus causing slight differences in odor."

COLD VULCANIZATION

IN the *Chemical Age* (New York) August, 1920, is to be found a discussion of the new process for cold vulcanization devised by S. J. Peachey, a lecturer in chemistry at the Manchester College of Technology. The new process depends upon the alternative exposure of the rubber to the action of two gases, sulphur-dioxide and hydrogensulphide. It is claimed that more rapid and complete vulcanization is obtained even at ordinary temperatures and the following results are given to support the claim that the processes are of fundamental importance:

Though sulphur vulcanization as distinguished from sulphur chloride treatment there yields a product comparable to that obtained by the Goodyear process. It eliminates the use of heat and also to a great extent mechanical pressure. The gases employed are easily produced at low cost on a large scale. The reaction proceeds rapidly and the manufacturers are enabled to employ organic filling agents which cannot be used in connection with hot processes, these including shoddy waste, saw dust, waste leather, etc. These materials are inexpensive and durable and by this process of vulcanization can be employed as floor and wall coverings and certain types of upholstery work and as parts of footwear. It is also said that different pigments and dye stuffs which are usually destroyed by the hot process can be used to obtain desirable delicate tints and shades heretofore unobtainable.

It is thought that the process can be extended to the vulcani-

zation of rubber in solution producing a stiff jelly in a few moments from which the rubber solvent could be driven off by evaporation leaving a fully vulcanized rubber. The use of the mixed solutions for producing perfectly vulcanized seams has already proved satisfactory in practice, inner tubes being repaired in a few moments. It has also been found that with the solution process, leather soles and heels may be attached without stitching or nailing and as a matter of fact, a shoe might be produced from reformed leather without any stitching whatever. Several pairs of shoes have been soled with the reformed process and practical tests of several months indicate that the resulting material is more durable than ordinary leather.

The process should lead to many other applications and while much of the work is still in the laboratory stage, the process itself is so simple that no difficulty should be experienced in taking it from a laboratory to a full commercial stage.

It might be added that the Goodyear process consists in incorporating sulphur and rubber and heating for a period of time, usually two to three hours at a temperature of about 140°C. This time has been reduced to some thirty minutes by recent researches involving so-called organic accelerators. The Hancock process consists in immersing sheets or formed articles of raw rubber in a bath of sulphur at a temperature of 135° to 140°C. and the Parkes method depends upon the immersion of thin sheets or films of rubber in a cold dilute solution of sulphur-chloride in carbon-bisulphide.

THE DIFFUSING POWER OF PIGMENTS

IN the September issue of the *Journal of Industrial and Engineering Chemistry*, W. K. Lewis and F. P. Baker report the results of researches on the diffusing power of pigments, the work having been undertaken in an effort to devise a method for determining the covering powers of pigments. The methods ordinarily employed have been unsatisfactory because most of them give relative values only and, besides, require complicated apparatus involving difficult technique. The new method does not measure covering power directly but it does give results which can be expressed in absolute figures and it has been shown that duplicate determinations by different observers in different observatories give comparable figures. The diffusing power as measured is the most satisfactory numerical expression of fineness for a given pigment, and as such is of direct value to the rubber trade.

In the present method the filament of an incandescent lamp is observed through a suspension of a finely divided solid in a suitable fluid, and light passing through such a suspension is so diffused as to produce a ground glass effect. The diffusion increases greatly with the number of particles and is probably proportionate to the total number of particles independent of their size. This diffusion then is the basic principle of the proposed method and is that employed in any turbidimeter where an object is observed through a suspension and the thickness of the suspension just required to blur the object is measured.

The phenomenon is not one of light absorption and it has been determined that the disappearance of the filament is determined by the amount of pigment per unit area of cross section of the cylinder, and is not influenced by the position of the pigment particles in the dilution. It is the weight of pigment in grams required for each square centimeter of section which is measured and results are reported as the reciprocal of this quantity, that is, the square centimeters of surface which one gram of pigment is capable of covering.

The diffusing power is not to be confused with covering power. The covering power of pigments is unquestionably influenced by their capacity to absorb light but the diffusing power is a direct measure of fineness.

The method has the advantage of allowing the determination of diffusing power notwithstanding the color of the pigment which is a considerable difficulty when covering power is to be found according to usual methods.

The tables which accompany the article indicate that in the case of carbon black the diffusing power increases with the time of grinding and also that results are independent of the concentration of the pigment, in the diffusing liquid. This also is shown by a series of observations with white lead in linseed oil without grinding. A third table gives the diffusing power of various pigments ground in linseed oil working with the more important ones as ordinarily found in commerce. These figures expressing square centimeters of surface which one gram of pigment is capable of covering are as follows:

White lead	260
Carbon black	2,200
Lamp black	1,830
Red oxide	348
Red lead	137
Zinc oxide	560
Whiting	295
Barytes	170
Lithopone	560

HEAT PENETRATION IN PROCESSING CANNED FOODS

THE above is the subject of a complete bulletin just issued by the research laboratories of the National Canners' Association, Washington, and reports the results of certain researches which have to do with heat penetration studies. Since the processing of canned foods has for its object the destruction of all minute forms which could cause a spoilation of the food, the importance of these studies is immediately apparent. It is the general practice to place the filled can of food in a sterilizer and raise its temperature by means of hot water or steam, the heat entering the container from all directions so that the temperature of the center of the can must be taken as the basis of any study. The determination of the most satisfactory methods for treating a given food material in the various sizes of cans hinges then upon the temperature of the center of the can during the processing and a knowledge of the length of time required to destroy all the spores of the most persistent organisms which may be present. As pointed out in the bulletin other studies are in progress designed to learn the temperature at which the most resistant bacteria are destroyed as well as the length of time necessary to destroy them at various temperatures in the case of different foods and this information will be the subject of a bulletin to be issued in the near future.

Of course this is not the first study having to do with the penetration of heat in canned food but it is perhaps the most scientific investigation in which new apparatus has been developed, and specifications for its construction are given in the publication. By its use it is possible to ascertain temperature at the center of a can being processed under ordinary commercial conditions and the provision of such an apparatus was one of the essentials to the success of the studies reported.

The report discusses the apparatus and method, the experimental rotating cooker employed in the work, the method of heat transfer, minimum heat penetration, and gives in some detail the form of typical heat penetration curves; the influence of the cooling operation on sterilization is discussed, the processing in dry steam and under water, the temperature reached at different parts of the retort, the influence of rotation and observations upon a considerable number of individual products. These curves indicate the length of time required for penetration of heat to a given temperature both as regards the material itself and the liquor surrounding it in the cans.

The bulletin concludes with an interpretation of heat penetration curves in terms of process time and points out very clearly a number of fundamental principles. While the bulletin is of first interest to those engaged in preservation of food by canned methods and in scientific studies on this important subject, it will also be found of rather wide interest and certainly demonstrates the fact that proper preservation

of food is more than a simple process and that it depends ultimately upon proper recognition of the scientific principles and their application to the work in its stages of development.

COLLOID CHEMISTRY AND ITS GENERAL AND INDUSTRIAL APPLICATIONS

THIS is the subject of a report made by the Department of Scientific and Industrial Research of Great Britain at the request of the British Association for the Advancement of Science. The department has previously published two other interesting reports and a third continues the discussion under ten headings. These are colloid chemistry of soap, ultramicroscopy, solubility of gases in colloid solutions, electric charging on colloids, inhibition of gels, industrial applications, and eight headings relative to colloid problems in industry. These discuss bread-making, two phases of phonographical application, cellulose esters, petroleum, asphalt, varnishes, paints and pigments, and clays and clay productions.

Under the section on colloid problems in bread-making we find statements which are interesting in view of the establishment last year of the American Institute of Baking which proposes to study the fundamental laws and principles underlying bread-making. "There is no manufacturer less aware of the chemical problems underlying his trade than the master baker. In spite of his ignorance, however, he is one of the most efficient members of society in that he produces an excellent article with great regularity. This is perhaps less a matter of wonder when it is realized that the art of bread making of a high order can be traced through the Chinese to about 2,000 years B. C. and is of course older than that.

Such scientific work as has been done in or for the bakery has usually been undertaken from some specific material object. There is comparatively little published work available to show that the problems have been tackled for a scientific purpose, or for improvement of the process. . . . Briefly put, bread is made from flour, yeast, water and salt with occasionally milk, fat, malt extract, yeast salts, wheat germ, aerating chemicals, etc., according to the quality of bread required. With the additions of any new ingredient to the first four mentioned, fresh complications in the chemical changes during bread making are introduced. Added to these must be considered the changes involved during fermentation and baking and one of the largest problems of all during the change from freshness to staleness." This part of the publication continues with a discussion of the different components presenting the changes which take place and the reactions which are important together with the deductions which can be made by the application of the principles of colloid chemistry. Similarly the other subjects listed are discussed at length so that the report assumes something of the character of a highly valuable text.

MOLASSES

MOLASSES has become of more and more interest to the chemist as new ways for its use and the use of its own products have been devised. It is probably the most important by-product of the sugar industry and forms the subject of a bibliography compiled by C. J. West and published by Arthur D. Little, Inc. The average composition of cane molasses is given as water 20%, sucrose 30%, invert sugar 32%, ash 6%, organic non-sugars 12%.

Molasses is the final mother syrup obtained in the crystallization of sugar and carries all the soluble impurities of the original juice which are not removed in the process of purification. The sugar present is that which refuses to crystallize out in the presence of the impurities and from 15 to 25 per cent of the sugar present in the original juice is usually to be found in the final molasses. In addition to some 36 pages of bibliography divided under six general headings, the bibliography discusses briefly six important uses of the molasses. These include the recovery of sugar, the production of alcohol which runs into millions of gallons annually, its use as a food both for human and animal consumption, its use as a fuel, as a fertilizer, and miscellaneous applications as in the leather industry where dressings and shoe blacking consume a certain quantity. In animal feeds, molasses is used to supply carbohydrate and to impart an attractive taste. It is usually absorbed on some such material as peat, bran, beet pulp, alfalfa, sphagnum moss and various kinds of metal.

ASSOCIATION OF WOOD-USING INDUSTRIES

A GREAT deal has been said and written concerning the conservation of forest resources and the present year has seen the formation of an association of wood-using industries which has been formed for the purpose of bringing about a certain measure of forest conservation through the better utilization of forest products. Mr. O. M. Butler, speaking before the association at its initial meeting, September 28th, states "stripped of ramifying and controversial details the forest problem comes down to the matter of providing timber to meet the forthcoming requirements of the wood-using industries of the country. There are two main lines along which that purpose is to be met. One is by protecting remaining forests and forest lands from fire and other natural destroying agencies and by bringing back to timber production cut-over forest land suitable chiefly for timber production. The other is by the conservation of the merchantable timber now standing by better utilization of the material cut or, expressed a different way, the curtailment of the annual drain upon the forests by more complete and scientific use of the trees cut." It is with the second phase of the subject that the new association proposes to be active. Some years ago it was pointed out that little more than one-third of the original tree reached the market and in many localities this figure remains correct today. As Mr. Butler points out, "It is easier to make one tree which you have in hand do the work of two than to raise two trees of which the seed is not yet planted."

Not only do we consume far more lumber per capita than any other nation, our annual requirements at present being approximately forty billion board feet but we also require our forests to produce one hundred and twenty million ties for steam and electric railroads and some four million cords of wood for the production of paper pulp in addition to two million cords for pulp by the ground wood process. The best utilization by chemical process by which the four million cords are treated is about 45 per cent of the wood substance, thus leaving 55 per cent of the original weight of the wood to be lost in the waste liquors. This then is the equivalent of more than two million cords of wood annually, not to mention the loss due to improper methods of storing pulp wood.

Without forgetting the importance of forest production it would seem that the field in which the new association intends to work offers opportunities for immediate results involving research important not only to those organizations and industries which use wood as such but also to a considerable number of activities which depend upon wood as a raw material for their chemical processes. This includes besides pulp and paper, the preparation of tanning materials, the various wood distillation processes, the natural dye stuffs, etc.

A SUGAR SUBSTITUTE

IN times past it was the custom to dust marshmallows with powdered sugar after they had come from the starch molds and were ready to be packed for shipment. This has proved to be an almost impossible practice of late and a substitute has appeared which seems to give satisfaction and being composed largely of materials of food value is in no way objectionable.

A recent bulletin of the Biscuit and Cracker Manufacturers Association Technical Bureau indicates that the analysis of these dusting materials shows them to be composed principally of starch, dextrine, and reducing sugars. Thus there is starch, 30.1; reducing sugars, 12.8; dextrine, 45.4; gums, 3.4; water, 5.6; fat fiber and lactic acid, 1.23. The material is very sweet, is white in color, and costs in the neighborhood of 8 cents per pound.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

By A. Slobod

ELECTRIC PLOWING

In France considerable attention has been paid to the development of electric plowing. A coöperative society was formed in the Meux region and is supported by the Omnium Français d'Electricité: A subsidy of 60,000 fr. was obtained from the Credit Agricolé, while the Ministry of Agriculture will advance 50 per cent to groups of seven or more for electric plowing equipment. Steam plowing costs 127.5 fr. per hectare, tractor plowing, 115 to 144 fr. per hectare and is limited to depths of 20 to 25 cm., while electric plowing costs only 110 fr. The energy consumption per hectare is 90 to 100 kw-hr. for deep plowing, 45 to 47 kw-hr. for medium plowing and 35 kw-hr. for shallow plowing. The equipment used by the Societé Générale Agricolé consists of two 90 kva. transformer trucks with special collecting gear, for 15,000/750 volts, three phase; two heavy windlass trucks with petrol engines for propulsion; two balance plows; and of material for erecting a short high tension temporary line to serve remote areas. The windlass trucks which also serve as tractors for the rest of the equipment have specially large and broad wheels. The windlass motors are of slip-ring induction type developing 80 hp. at 960 r.p.m. and capable of carrying 100 per cent overload momentarily and 50 per cent for five minutes. The petrol engine can be used in emergency to drive the windlass. A change speed gear is provided allowing four different speeds. About 4 hectares per day can be plowed with the present equipment. New windlasses will be provided with 120-hp. motors. A recent report discloses that 1,600 electric plowing equipments have been installed in Germany since the war.—*Revue Générale de l'Electricité*, Feb. 22, 1919. Condensed in *Electrical Review*, Chicago, June 14, 1919. This subject is further dealt with in detail by H. Guédeney in *Bulletin de la Société Franç. Elect.* for February, 1920, Vol. 10, pp. 57-78, and abstracted in *Science Abstracts*. After giving the figures of the effort demanded according to the depth of plowing and the character of the soil, the author states that the smaller class of plant—30-50 hp.—is the more generally useful and that the whole of the plant should be so constructed that it can meet the sudden shocks or peaks continually occurring. Robustness and simplicity are important as skilled labor cannot be employed. Lightness is desirable and so the soil should not be compressed. The price should be such that the plant is within the means of three or four small farmers acting in combination.

The Howard system is described in detail. This comprises a lorry equipped with an electric motor driving a winch with a simple form of control, together with two anchoring trucks fitted with a grooved wheel for changing the direction of the steel cable attached to the plow. These trucks are made to move into the required new position by the pull of the traction cable. The wheels are provided with disks which project sufficiently into the soil to anchor the truck. The equipment is completed by two fixed pulleys at the corners of the field. A high tension line with portable transformers can be used if desired. A square of nine hectares can be plowed with one setting of the plant.

Some actual figures are given and also calculated costs of which the following is a summary:

First cost of plant, 100,000 fr., including 500 meters of portable line.

Capacity, 2.5 hectares (5.5 acres) per day.

Consumption of energy, 90 kw-hr. per hectare.

Working cost per hectare (depth, 30 cm.); current (40 centimes per kw-hr.), labor, etc., 47.70 fr.; transport of plant, 6.25 fr.; depreciation (7.4 per cent) and interest (6.5 per cent), 46.33 fr.; repairs, 11.70 fr.—total, 111.98 fr.

The corresponding figures are 302.5 fr. for horses and 288.85 fr. for oxen.

THE ELECTRICAL INDUSTRY OF SPAIN

The beginning of the Spanish electrical industry dates back to the eighties of the last century when most of the undertakings were controlled by German capital; the A. E. G. and the Schuckert were particularly successful and were awarded most of the contracts for construction and equipment. It was the period of direct current generated by steam. The Southerner's love for comfort and fancy lighting effects led to the rapid development of the power plant. Toward the middle of the nineties there began also to appear a considerable demand for industrial power; this prompted the extensive utilization of the numerous waterfalls. The hydraulic plants were of primitive nature as low cost of installation was then the first consideration. They were built for the two-phase or the three-phase system; 5,000 volt pressure was used. They had very poor regulation and gave quite unsatisfactory service. However, as gas companies existed only in the largest cities, most of the Spaniards exchanged their tallow candles direct for electric light and, therefore, they were not used to standard conditions of operation.

The second period of development dates from the beginning of the twentieth century when the native capitalist realized at last the importance of the hydroelectric power and readily financed all new undertakings. 15,000 and higher voltages were adopted; the earliest 60,000-volt installation of Europe was in operation in Spain. The former steam power plants of the principal cities began to lose their importance; they were now needed mostly in case of disturbances which cannot be avoided on high voltage transmission lines.

Three distinct regions of energy consumption could be observed by that time: (1) Madrid, the capital of the country, having no important industries and consuming electricity mainly for lighting purposes. (2) Barcelona, the main center of business and industry and the largest seaport of the country, with Catalonia in the background with its dense population and big industries. (3) Bilbao, the center of a rich iron ore region. Consequently all the power plants have their lines laid out toward these centers.

About 1910 a new phase of the development of the electrical industry was initiated. It was characterized by the efforts made to consolidate the organization of the new undertakings as well as of the existing plants from the technical as well as from the financial standpoint. A scheme for the interconnection of all the important plants is being developed; higher transmission pressures—100,000 volts and over are being planned so that the most distant waterfalls could be utilized. New laws were recently passed which place water power concessions on the basis of a public utility of high value. A plan has further been contemplated to nationalize all water power not previously worked so as to give the government all rights to expropriation.

The nine leading electric power concerns are briefly described. They are led by the Barcelona Traction Light and Power Company of Toronto, Canada. There are also 58 smaller plants ranging in capacity from 9,000 to 800 horsepower and 50 plants having capacities from 800 down to 300 horse-power. According to the statistics of 1917—the latest available—the total utilized horse-power was 384,297, which

at present must be about 500,000; about 200,000 additional horse-power is used for direct mechanical energy. As the total water power of Spain is estimated to be 5 million horse-power it is seen that only 14 per cent of the total available power has been utilized so far. However, all the large power plants are planning further extensions, and the final goal will evidently be the complete electrification of industry and home.

The main three loads for all these plants are (1) the electric railroads, (2) the various industries, and (3) electric lighting.

All the larger Spanish cities have electric railways; they usually are efficiently operated. There are also a number of suburban and interurban lines. The total length of the entire street railway system of the country, including the suburban lines, is about 700 km. and is rapidly increasing. Since the fall of 1919 the Spanish capital has its first subway. It is called the "Metropolitane" or the "Metro," is 45 km. in length and is operated by direct current of 550 volts pressure taken from overhead lines by pantographs. A storage battery provided for emergencies will supply the whole system for one hour. The cars are of steel and have each two 175-horse-power motors of American make. The trains are composed of one car and one trailer and accommodate 200 passengers. The subway runs now from the center of the city to the north terminus, and work is going on to extend the line from Puerta del Sol to the south terminus. There are also about 65 km. of electric trunk lines and about 60 km. are in process of construction. A general electrification of the Spanish railroads will probably not be considered within the next few years as there is yet no such passenger or freight traffic as would repay the very expensive conversion of the system.

Electric lighting is used freely but the electric system is poor from the engineering and structural standpoints, and so is the installation work, especially in regard to safety appliances. However, it must be admitted that very few accidents happen as a result of such installations; this may be due to the generally dry and warm climate. Metallic lamps are generally used; arc lamps are not much in use.

The electro-chemical and the electro-metallurgical industries are growing rapidly. About 15 million tons of calcium carbide is produced annually by fifteen plants. Two other factories manufacture electrolytic chlorine and caustic soda. Considerable capital has been invested in plants for the production of nitrogen fertilizer by the Norwegian process.

The manufacture of electrical apparatus reached considerable dimensions even before the war. With Germany suddenly eliminated as a source of electric apparatus and supplies, Sweden and Switzerland were the only other sources available. Neither England nor the United States were active competitors. Their product is not quite up to the Spanish requirements, being of high quality and consequently too expensive. As a result of all this the Spanish national electrical industry has greatly developed since 1914, so that the domestic production entirely satisfies the home market in many lines.

The following products might at present be imported by Spain: Large electric generators and transformers; special machinery for quarries, mines and crane installations; electro-chemical and electro-metallurgical equipment; high voltage apparatus and switchboards; measuring instruments and meters; also telephone, telegraph and electro-therapeutic apparatus.—Blumenthal *Elektrotechnische Zeitschrift*, April 1, 1920,

RECENT PROGRESS IN PHOTOMETRIC METHODS

A very novel method of computing the distribution of illumination on the working plane has been devised in Germany and described in *Zeitschrift für Beleuchtungswesen*, January 31, 1920. A concentrated filament, approximately a point source, is mounted in a spherical bulb which has etched on its surface meridians and parallels dividing it into one hundred parts of equal areas (deka-space-degrees). The lamp is mounted above a drawing of the space to be illuminated, and the etched lines cast shadows making it possible to count the number of space-degrees on the plane. From the photometric distribution curve the flux in each zone is determined, and the space-degrees in any zone on the plane have the same flux as that from the corresponding zone of the lamp bulb surface. The total flux incident on the surface will be the sum of that contributed by each lamp. A modification of this idea involves a cubical box having a blackened inner surface and a removable bottom. For the latter is used any one of a series of glass on which are photographed the projection of the lines etched on the original bulb with suitable notations which would differ with the lamp used. The notation gives the flux per space-degree in each zone, the flux in the entire zone; the area covered by each space-degree for the height of the lamp, and the illumination in flux under each condition.

In order to predetermine the range of light house illumination a laboratory experiment has been devised (*Comptes Rendus de l'Académie des Sciences*, October 6, 1919, p. 616) in which a sieve is made up of a series of vertical metallic plates pierced with holes in groups of four of small diameter, rigorously calibrated and placed on parallel horizontal lines. The sieve is placed before the mirror reflector, and the parallel beams of light passing through the holes are received on a screen, and those which would reach the horizon are readily picked out. By turning the mirror the region active in this direction may be determined. From a plot of the distribution the range may be calculated.

In the photometry of lamps with reflectors where the inverse square law does not apply, certain conventions have become more or less standardized by practice. In the case of searchlights using parabolic reflectors it has sometimes been assumed that the inverse square law holds if measurements are made from a point in space behind the mirror. Experiments have been made which indicate that for distances greater than a certain limiting value, the inverse square law can be applied if the distance is measured from the mirror itself (*Zeitschrift für Beleuctungswesen*, April, 1919, p. 35). Allowances and corrections must be made for atmospheric absorption and for aberration.

Elektrotechnische Zeitschrift for January 8, 1920, p. 25, describes a method for the graphical determination of the illumination produced from the polar candle power curve of the source. It is based upon conditions of proportionality of similar triangles. Right-angled triangles and a compass are the only tools needed, and the simplicity of the method is cited in favor of its practicability. It may also be used to construct the polar curve which will give a desired illumination curve.—Report of the Committee of Progress, Illuminating Engineering Society, October, 1920.

A NEW ELECTRICAL PRECIPITATION TREATER

A contribution to the *Journal of the A.I.E.E.* for October, 1920, under the above heading gives the description and theory of a new electrical precipitation treater with results of experimental tests in the Electrotechnical laboratory in Tokyo as well as practical application in the factory at the Nikko Copper Refining Works, Japan.

Since the Cottrell system of precipitating dust in gases was first applied at the Selby Smelting and Lead Co. at San Francisco Bay about ten years ago, it has made remarkable progress in its practical application in this country as well as abroad. The extent of application of electrical precipitation in Japan can be seen from the following:

Eight treaters have been built and are now in successful operation, and a number of Japanese concerns are at present actively considering the installation of electrical treaters.

In the modern precipitation treater the electrodes consist of a metal cylinder as the passive electrode and a bare wire or a metal chain, supported along the center of the cylinder, as the active electrode. When such a treater is used for gases of smelting furnaces or other corrosive gases such as are pro-

duced in some electrochemical works, the electrodes are acted upon by the corrosive precipitated particles with the result that the life of the active electrode is unduly shorted and that sparking often occurs between the electrodes which in turn often causes damage to the transformer and in general prevents the application of the system to combustible substances.

To overcome the obstacles enumerated, the authors of the above-mentioned article (Motoji Shibushawa and Yasujiro Niwa) have introduced important modifications in the modern precipitation treater, which have proved successful both in the laboratory and in the factory. In the early type of precipitation treater insulating pieces are sometimes attached to the active electrode for the purpose of increasing brush discharge and precipitation efficiency. On the other hand, the fact that the air in the crevice of the power line insulator is subjected to a much higher potential gradient than when the insulating substance is absent lead the authors to the following conclusion: It is possible that the high potential might ionize the air across the insulating medium, and that therefore electrical precipitation might be possible with electrodes entirely covered with insulating material such as glass, etc.

An electric treater was therefore constructed on the same principle as the standard modern treater, except that the electrodes were entirely separated by dielectric substances, such as glass, porcelain, etc., and a series of successful experiments were conducted in the Electrotechnical Laboratory.

Most interesting, however, are the results of the practical application of the authors' treater at the Nikko Copper Refinery Works. In these works of the Furukawa Mining Co., Ltd., where approximately 50,000 tons of copper per annum are electrically refined, an electrical precipitation plant was recently installed. The function of this electrical treater is to recover precious particles in the mixed gas from roasting coupellation, reduction and reverberatory furnaces which are used for the purpose of separating silver and gold from slimes precipitated in electric baths. The treater consists of one section of 32 pipes, arranged in a rectangle 8 by 4. These pipes are 12.5 inches inside diameter by 16 feet long. The active electrode is No. 14 steel wire stretched concentrically from lattice work. The electrical outfit consists of a 10 kva. 200 to 100,000 volts transformer and a rotary arm type rectifier driven by a 1.5 hp., 200-volt, three-phase induction motor. There are several taps in the low tension winding, which together with a rheostat in the transformer primary circuit, can be used to produce any desired voltage.

For the purpose of the test the active electrodes of the treater were covered with soda glass tubes, the outer diameter being ⅜ to ¼ inch and the thickness 1/16 to ⅛ inch. Four such tubes were required for each electrode. The tests were conducted for a period of a little less than two months and the following conclusions and results were arrived at:

(1) With regard to vibration of active electrode and sparking between electrodes. It is a well-known fact that the periodical static force acts upon the electrodes of the treater, causing vibration of the active electrode, which in turn is the chief cause of sparking and consequently wasting of the active electrode. These troubles were actually experienced at the Nikko factory. But since the active electrodes were covered with glass the vibration had entirely ceased and practically no sparking occurred.

(2) The deposit of dust on the active electrode, which is objectionable, is reduced to a minimum with the new treater.

(3) Current, input and precipitation efficiency. Careful tests were made to obtain this data for a treater with bare electrodes and for the same treater with the electrodes covered with glass. A comparison of the results obtained shows that the current and input are much reduced by covering the electrodes with glass. The precipitation efficiency at voltages below 50,000 is lower for glass-covered electrodes, but above this critical voltage the efficiency is higher. With bare electrodes operated at 50,000 volts the efficiency is 87 per cent and the input 1.2 kw., whereas for glass-covered electrodes at 55,000 volts (increased by 10 per cent in voltage) the efficiency is 94 per cent and the input 0.5 kw., which shows considerable saving in power. Having established by actual practical results the advantages of the treater with glass-covered electrodes, the authors attempt to answer the question of how the current passes through the glass. A very interesting theoretical discussion, as well as a series of experiments are given hearing on the subjects of potential gradient, passage of current through the glass, variation of resistivity of glass with potential gradient, variation of resistivity of glass with temperature.

From these the following conclusions are drawn with regard to the reason why so large a current is permitted to flow through the glass as to enable electrical precipitation with glass-covered electrodes:

(1) Resistivity of glass decreases with temperature as well as with potential gradient applied.

(2) Free changes appear on the surface of the glass placed in the electric field, which causes in the dielectrics a potential gradient much higher than that calculated by mere static consideration.

(3) As the current necessary for the electrical precipitation is very small, the above-mentioned two causes permit a sufficient current to enable electrical precipitation.

COMMERCIAL APPLICATION OF ELECTRICAL OSMOSIS

THE addition of a small amount of alk. to a suspension of clay in water results in the suspension of clay particles in water while pyrites, mica, free silica and other impurities settle to the bottom. Fine particles which do not settle may be removed by the osmotic process. Bodies which remain in suspension and tend to move toward the cathode, require an electrolyte of an acid character to bring about dispersion or peptization, but bodies which tend to move to the anode require an alk. electrolyte to cause dispersion. Osmosed fireclays are entirely free from pyrites and goods made therefrom are not subject to green stains when glazed. By the use of fine osmosed kaolin chemical porcelain has been produced of the highest quality, the body being made of pure kaolin, which, owing to the fineness of particles, completely vitrifies. There is also a better locking of the glaze to the body by fine sillimanite crystals, which form on firing and penetrate the glaze. In clays themselves the extremely fine particles could be separated from the coarser.

Another application is the electro-osmotic filter press. The press consists of a series of chambers into which the suspension is fed under a head of ten feet, sufficient to insure a rapid filling of the chambers. The chambers are closed on both sides by filter cloths in the ordinary way, but the cloths are held in position by perforated or grooved metal, carbon or other conducting plates, one of these plates forming the cathode and the other the anode. An electric pressure of 20 to 100 volts, depending upon the substance, is necessary. In this press very fine material which would clog up the ordinary filter press can be dewatered.

H. Jackson stated that by using a well-known clay for a muffle he was able to get only 24 hours' service from same. By treating this clay by osmosis he made muffles from which he got 10 to 15 times the service. Ormandy stated that a muffle made of osmosed clay lasted thirteen journeys whereas the muffle made of the same clay not treated would never last more than three journeys. With the finest English china clay which had been treated with 87 tons of water in order to wash three tons of clay, it was still possible to separate 7 per cent material from the clay.—J. S. Highfield, W. R. Ormandy and Northall.—*Pottery Gazette*, Vol. 45, pp. 775-77 (1920); also *Journal of the Royal Society of Arts*, 1920.—Abstract in *Journal of the American Ceramic Society*, August, 1920.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

LOW-PRESSURE STEAM CONTROL DEVICE

By J. W. Smith

In a mixed-pressure steam turbine and electric generator installation placed in the power station of an English factory there was no provision made for automatically cutting off the last expansion stage of the turbine from the exhaust main when the supply of exhaust steam failed.

When the air supply of the steam fell below the quantity which could be passed by the low-pressure starting valve a partial vacuum was induced in the exhaust main, which, in this case, is about 400 yards long, with the inevitable result that air was drawn in through some leaky joint or open drain cork. The starting valve could be regulated by hand to pass only the proper quantity of exhaust steam, but such a solution of the problem was troublesome and would mean that one man's whole time would be occupied. Instead it was solved by putting in an automatically operative controller.

First, there is a low-pressure receiver which diminishes the fluctuations in pressure of the exhaust steam from steam-

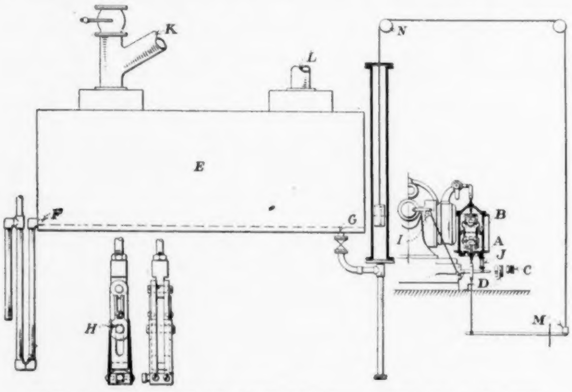


FIG. 1. DIAGRAM OF CONTROLLER USED ON A MIXED PRESSURE STEAM TURBINE

driven machinery, such as steam hammers and non-condensing steam pumps. After leaving the receiver (Fig. 1) the exhaust steam enters the low-pressure chest through pipe C, then passing downward through the starting valve and upward through the emergency stop valve and the governor throttle valve into the turbine.

The turbine steam chest is fitted here with an emergency drip-stop valve A which closes upward and the spindle passes vertically through the bottom governor. This valve is of a piston type and is a duplicate of the governor throttle valve B fitted immediately above it. As arranged by the makers it was connected to its opening lever by a pair of short links C. These links were replaced by some longer ones with a distance piece riveted between their ends to form a flat surface D, and the bottom holes of the new links were elongated to allow the valve to be closed without raising the original operating lever. Under this, against the wall of the condenser pit, was fitted a lever about 4 feet 6 inches long. At about 3 inches from its fulcrum a vertical rod was jointed which passed through a suitable guide so that its end was just clear of the flat bottom of the new valve links, when the new lever was at the bottom of its travel. The end of the lever had to be raised about twelve inches to close the valve, and suitable guides and stops were provided to prevent all undue stresses. Owing to the 18 to 1 leverage provided, the effect of the friction of the valve and spindle was negligible at the end of the lever. The steam receiver E, the shell of an old Lancashire boiler, had a syphon drain F connected to one end plate about 3 inches above the bottom of the shell. In consequence of the position of this drain there was always a quantity of water lying in the bottom of the shell, the surface of which measured 3 feet by 20 feet. At the other end of the steam receiver the old blow-off cock fitting G at the bottom of the shell had been blanked off. A 2½-inch cock was fitted to this blow-off cock branch one week end, and, working back from that the following week, we rigged up in a vertical position an old 7-foot length of 8-inch cast iron pipe, and supported it from the floor by a length of 2½-inch pipe with a blank flange at the bottom. This pipe formed an excellent float chamber with sufficient head of water to seal the maximum pressure permissible in the receiver. Owing to the wide ratio between the surface of the water exposed to the steam on one leg of the submerged bend, and the surface of the water exposed to atmospheric pressure on the other leg of the submerged bend, about 60 feet square to 50 square inches, the rise of water in the float chamber was almost 2.3 feet per pound pressure in the receiver. A galvanized iron float was provided, 6 inches in diameter by 12 inches deep, with a stretcher bar across its open top to enable it to be suspended correctly. This was filled with water and connected to the new lever by a flexible steel wire rope passing over two guide pulleys. Sufficient weight was then added to the lever to cause the float to be normally half submerged when the lever was clear of both stops.

It was found in tests that the displacement of only 2 inches of water above or below the center of the float is sufficient to operate the valve and that only ½ pound variation of steam pressure is required to move the valve from "open" to "shut," or vice versa. Moreover, it is also stated that the device has been in constant use for eight years without any repairs.—Paper read before the Gloucestershire Engineering Society. Abstracted through *Power House*, Vol. 13, No. 19, Oct. 5, 1920, pp. 437-439.

REGAN AUTOMATIC TRAIN CONTROL SYSTEM

This system, as installed on the Great Eastern Railway where the Westinghouse brake is employed, consists of a shoe suspended from the center of the rear buffer pin of the engine, an electro-pneumatic valve behind the steps on the right side; a relay box and release switch on the same side; a battery box and a speed-control device on the right wheel of the controlling nozzle. The equipment on the track consists of a ram 100 feet long with inclined ends fixed in the "four-foot" at each signal and electrically connected thereto.

The speed control device consists of a centrifugal governor mounted upon a base plate rigidly bolted to the end of the trailing nozzle and accurately centered therewith.

The shoe mechanism consists of a shoe stem, a cylinder and a circuit controller. The upper part of the stem is connected to the brake pipe and, as the stem is hollow, it follows that should the shoe be broken off the air would escape and the brake would be automatically applied.

A demonstration of this system was given on the Great Eastern Railway on September 30, 1920, when the speed control was set for 24 miles per hour and the train was stopped from that speed in 225 feet.

In this connection there is an editorial in *The Engineer* (pp. 355-356) in which automatic train control is advocated for Great Britain and instances are cited of serious accidents

which could have been prevented had such a control been available. In fact, it is stated that the Ministry of Transport has appointed a Department Committee to consider the whole question.

In discussing the matters to be considered by this new committee the editorial points out as one having a very serious aspect, the question whether or not the uniform system for the whole of Great Britain should be determined upon. This is particularly important as British locomotives do a considerable amount of running over "foreign" tracks. There is also a question as to what object automatic train control has achieved; this is, whether or not the driver should have an indication of the state of the running signal which he is unable to see, for example during fog or falling snow.

An interesting discussion is presented as to the conditions which the track equipment should satisfy. The subject of speed control is also not as simple as it looks, as, for example, it is not easy to insure that a mixed traffic engine just taken off the freight train is properly adjusted for working an express passenger train and vice versa.—*The Engineer*, Vol. 130, No. 3380, Oct. 8, 1920, p. 348.

GOVERNMENT TESTS OF WATER INDICATING DEVICES

FOR the purpose of determining, if possible, the general outline of the flow of water existing at the back head, when high evaporation was taking place, tests were made on one of the U. S. Railroad Administration standardized 2-10-2-type locomotives.

In these tests it was found that the way the top connection to the water column is made affects very materially the general outline assumed by the water on the back head. It also appeared that under certain conditions dry steam was being obtained both at the back knuckle and further ahead, which is believed, however, to be partly due to the exceedingly good water used in this test.

Further tests were made to determine the approximate outline and proportions of the water conditions existing at the back boiler head, while the locomotive is being operated with heavy throttle, or when steam is being rapidly generated and simultaneously escaping from the boiler. These tests covered the distance of 808 miles in bad water districts on approximately level track with a locomotive of the heavy 2-8-2-type equipped with superheater and duplex stoker.

The tests appliances are shown in Fig. 2. The apparatus consisting of four gage cocks applied directly in the back head near the knuckle; one water column to which three gage cocks and one water glass were attached; one water glass with a 9-inch reading, standard application, with both top and bottom cocks entering boiler back head direct; one water glass applied for experimental purposes with a bottom cock entering the boiler head on back knuckle and one entering 13-inch boiler head on back knuckle and one entering 13 inches ahead of the back knuckle, together with four exploration tubes or sliding gage cocks. Fig. 2 shows a side elevation of these exploration tubes.

Here it was found that while generally the same conditions prevail as in other tests the outline of water reached a higher elevation and greater proportions at the back head than in the previous tests, which is due probably to the poor water used here.

Tests were also made on a switching locomotive in which, in addition to the usual apparatus, a glass tube was inserted in the top of the wrapper sheet which permitted the use of an electric light inside the boiler, clearly illuminating the steam space over the crown sheets. Five bulleye sight glasses were distributed so that the action of water in the back head could be seen while under steam pressure, as shown in Fig. 3.

Both main rods were disconnected, cross heads blocked at end of stroke and valve stems disconnected and so placed that steam was discharged through the exhaust nozzle and stack, creating a forced draft on the fire, representing as nearly operating conditions as possible.

When the throttle was closed and no steam escaping from the boiler, the surface of the water was approximately level, with a distinct circulation noted from back to front and from the sides toward the center of the crown sheet. When the safety valves lifted, the water rose with fountain effect, around

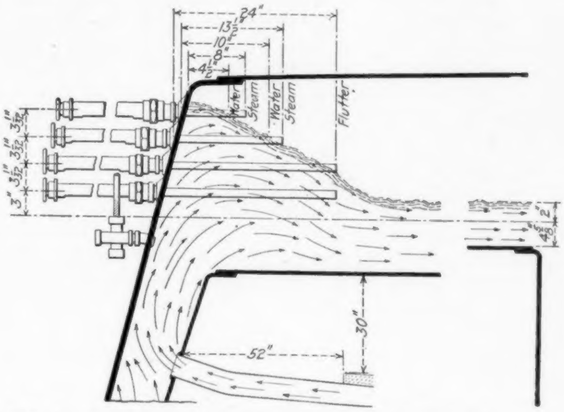


FIG. 2. EXPLORATION TUBES USED AS WATER INDICATING DEVICES IN TESTS OF WATER CIRCULATION IN LOCOMOTIVES

the edges of the firebox, from 1 inch to 2 inches, and the circulation was materially increased.

When the throttle was opened and steam was being generated and escaping from the boiler in greater volume, the level of water throughout the boiler was seen to rise 1 inch to 1½ inches, which rise was registered by the water glass, and a marked flow of water, with fountain effect, was observed rising around the firebox at the back head and wrapper sheets, reaching a height above that over the remaining portion of the crown sheet of approximately 2 inches to 4 inches, in proportion to the amount of steam being generated and simultaneously escaping from the boiler.

The important feature to be noted is that this height of water, as seen at the back head, was approximately 4 inches at its maximum, and was registered by the gage cocks, while at the same time it could be seen that the water glass was registering the level further ahead over the crown sheet.

Among the interesting features observed were the size of the steam bubbles which were approximately ¼ inch to ⅜ inch in diameter, and the rapidity with which they were seen to rise to the surface and explode. The size and number of these steam bubbles, which were seen rapidly rising next to the back head, explain one of the physical reasons for the increased height of water around the crown sheet and the rapid circulation attained.

These observations establish beyond question that when

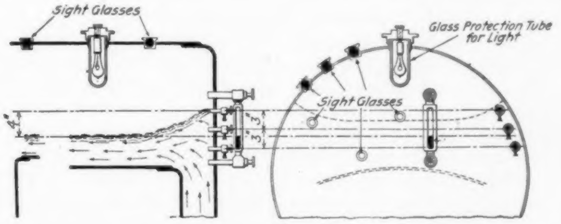


FIG. 3. ARRANGEMENT OF LIGHTS AND OBSERVATION GLASSES IN BOILER TO DETERMINE WATER CONDITIONS

steam is being generated and escaping there is an upward movement of water at the back head of the locomotive boiler which carries it above that further ahead over the crown sheet, and that the gage cocks, when applied directly in the boiler, register this rise of water and do not indicate the level further ahead, while the water glass registers the level of

water further ahead and not the fountain of water at the back head.

Among the general observations made attention may be called to the following: It is recognized that the volume of water in the boiler increases in proportion to the amount of steam being generated and in the same ratio that the steam bubbles below the surface are formed and expanded, the volume of which depends to a very considerable extent upon the purity of the water in the boiler and its ability readily to release the steam being generated, consequently increasing the height of water in the same proportion, which height is registered by the water glass.

Gage cocks secured directly in the boiler have been shown to be incapable of correctly indicating the general water level and an arrangement is described and illustrated in the report which is claimed to be more correct and safe than the ordinary methods.—Report of the Bureau of Locomotive Inspection of the Interstate Commerce Commission. Abstracted through *Railway Mechanical Engineer*, Vol. 94, No. 10, Oct., 1920, pp. 630-633. This is the second part of the report, the first part having been given in the *Railway Mechanical Engineer* Sept., 1920.

REPORT OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH FOR THE YEAR 1919-1920

FROM the report presented it would appear that a very active program for research is being steadily pushed ahead in England and that quite substantial funds are available for this. In particular, it is pointed out that the British industries with an awakening interest in the value of research and of scientific control of manufactures, are making such demands on the available supply of research workers and offering such salaries that the universities face the danger of losing their teaching staff in the same manner as they did during the war.

Important grants have been made to students and independent workers as well as to provide professors with research assistants of scientific standing. No conditions are attached to the grants made to workers whose sole aim is the extension of knowledge, either as to the line of their work or as to the use of the results. The only condition is that if they propose to make commercial use of their discoveries they must consult the Committee for Scientific and Industrial Research, because at this point they are leaving the field of pure investigation. Otherwise, however, their tenure of the grant is perfectly free.

There are now eighteen research associations of various character in England licensed by the committee and covering many fields of industry, and five other associations have been approved but have not received their licenses.

The Department of Research is committed to a total expenditure of £450,000 on account of the established research associations and has a further expenditure of at least £120,000 on account of those approved but not yet licensed. The total commitments may, however, reach £800,000.

It is claimed that the industry fully realizes already the importance of research though they have not yet quite come to a full appreciation of its difficulty or its full worth. The best proof that the value of research is realized is that large funds for the endowment of research are being raised privately; for example, the cotton industry is hoping to raise £250,000 for that purpose.

The report mentions more or less briefly the method of organization of research and the subjects which occupy the attention of the various boards and committees.

In this connection, it is of interest to note that the question of fuel is considered to be a basic problem of the greatest national importance. As regards the Committee of Research it is in the hands of a fuel research board. There are numerous other boards covering the vast field of investigation.

As a sample of the work of these committees may be mentioned the following quotation describing the Zirconium Inquiry Committee:

It was frequently suggested during the war that zirconium-containing steels of remarkable hardness had been produced and were being employed by enemy countries in the production of light armor for airplanes and tanks. In July, 1918, at the request of the Ministry of Munitions, a Zirconium Inquiry Committee was set up with the object of investigating the preparation of ferro-zirconium and, from the latter, of zirconium-containing steels. The experimental difficulties in the way of production of a true alloy of iron and zirconium were numerous and severe, and after much work they were only partially overcome. It was found possible to prepare, in 50-pound batches, a ferro-zirconium containing, however, a considerable portion of carbon, while much of the zirconium in the material was present as carbide. It was consequently very doubtful whether the zirconium in this material could be transferred into a melt of steel. In the meantime numerous inquiries have failed to discover any source of supply of ferro-zirconium containing only small proportions of carbon and silicon, or any evidence that zirconium added to steel conveys to it any beneficial quality. Further, the examination of samples of light armor of enemy origin has not revealed the presence of zirconium.

After the conclusion of the war the importance of the inquiry diminished and in consequence the committee were of opinion that their investigations should be concluded. We have recently received their report and have recommended that it be communicated to the fighting services.

In an appendix some information is given on the developments of the organization of research in the Overseas Dominions and in the allied and associated countries.

In particular, there is under consideration the proposal for the establishment of a National Research Institute for Canada, on which the report of the committee was unanimously adopted by the Canadian House of Commons in May last. The cost of building and equipping the institute is estimated at $600,000 and approximately $50,000 is required for the salaries of the staff during the first year. The proposed institute will exercise functions akin to those of the Bureau of Standards in Washington. It is also anticipated that the institute will play an important part in fastening the movement for coöperative research among the industries of Canada by placing laboratories and if necessary staff at the disposal of coöperative research gilds when they are not in a position to maintain laboratories of their own.

There are already several organizations in Canada established with a view to industrial research, such are, for example, the Fuel Research Board appointed to deal with the standardization of coals through the Dominion, and the Peat Commission, which has already successfully developed a log at Alfred, Ontario.—Abstract of Fifth Annual Report of the Committee of the Privy Council for Scientific and Industrial Research, presented to Parliament by Command by His Majesty and published in London in 1920, 120 pp.

THE DESIGN OF WAR VESSELS AS AFFECTED BY THE WORLD WAR

BY REAR ADMIRAL DAVID WATSON TAYLOR

IT is not fully possible as yet to answer the question, "What has been the effect of the World War on warship design?" and the opinion of the service has not yet been crystallized and become definite in this respect.

From such data as are available some facts may, however, be considered as established—one of them being the ability of the large, modern, heavy-armored ships not only to survive but to continue in action after the most severe punishment.

Taking the battle of Jutland as a test of the defensive qualiteis of modern ships, one finds that in the entire action only four such ships, all of them of the battle-cruiser type, were lost as a result of the action. The four outstanding facts of interest to the designer as they emerge to the author's analysis from the smoke and flames of the battles are—first, the value

of armor protection; second, the necessity for the maximum number of major caliber guns; third, the tactical value of speed; and fourth, the futility of subjecting all the ships to the attack of modern weapons.

Protection of ships is being recognized as one of the most important problems and both the British and American naval services have solved this problem so far as the torpedo has been developed to date. Moreover, although the solutions differ radically in detail they do not differ much in underlying ideas.

Of the general phases of the war the submarine campaign is given considerable attention. Nations must in the future be prepared to find the submarine playing an important part in attacking and throttling enemy commerce, even on their own coasts. The proposal brought forward at the Peace Conference to abolish the submarine entirely by international agreement was not adopted, wisely as the author thinks, for so long as the possibility of war remains, progress of size and engineering and their application to the art of war cannot successfully be throttled unless there is complete unanimity of sentiment throughout the civilized world.

War experience developed certain facts regarding submarines. It is essentially an instrument of stealth. Once detected, it is at the mercy of a surface vessel and detection devices while not perfect yet, have been and will be steadily improved as time goes on. If we had today an accurate device which would locate a submerged submarine with reasonable approximation several miles off and with accuracy when 100 to 200 feet directly under the surface vessel, the submarine would be obsolete as a weapon of war.

The position of the destroyer as an element of the fighting navy has been particularly enhanced as a result of the war experience, both to attack the enemy and protect its own capital ships. As regards the design of destroyers, the principal demand has been for greater cruising radius and increased shelter and comfort for the personnel.

The rôle played by trawlers, drifters and other small vessels of a similar type has been changed somewhat from that intended at the beginning of the war. Primarily they were to be used as mine sweepers and tenders, but the development of the depth charge made it possible to employ them against submarines, which, in fact, became the principal use to which these small boats were put during the last year and a half of the war. In fact, as time went on, special boats of small sizes were developed for this kind of service, such as the British patrol boats and the United States Eagle boats.

Aircraft carriers are particularly mentioned as a new and large type of naval vessel. The actual offensive use of aircraft against naval vessels was little developed during the war.

The author believes that developments in the air will be both along lines of offense against capital ships and of defense of them by auxiliary and offensive aircraft. He states, however, that the big ship which must be protected from projectiles of a ton weight falling at angles of 30 degrees fired from ships almost out of sight of the horizon, is not yet in serious danger from bombs carried by present-day aircraft with chances of hitting small indeed. It seems probable that aircraft will sooner become dangerous to destroyers and light vessels generally than to the large ships of the line and even then, in order to perform efficiently their functions with the field aircraft, must have means for being carried with the fleet, not only on long cruises but actually in battle, which account for the development of the aircraft-carrier type of ship.

To sum up, the experience of war so far as it can be grasped to date, has resulted in demands of every existing type of war vessel which can only be made by increased size and cost. It has resulted in the introduction of only one new type of major importance, namely, the aircraft carrier, but it has introduced a number of small types which will probably survive but need not be constructed in large quantities in time of peace.

While the present tendency is toward increased size and cost this very fact under the present financial economical and political conditions in the world may actually result in the long run in the disappearance from future building programs of these very types and the substitution for them of smaller and cheaper units made possible by new developments in size and engineering.—*Journal of the Franklin Institute*, Vol. 190, No. 2, Aug., 1920, pp. 157-185.

Progress in Mining and Metallurgy

Abstracts of Papers and Recent Articles

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

BY-PRODUCT COKE OVENS

By G. W. MARSHALL

THE primary and chief product of a coke plant is metallurgical coke, which is practically all consumed in blast furnaces and foundries. I would like to mention a few points embodying the result of my own experience.

First, do not forget that the foundations are the foundation of the whole plant. If you must economize, practice on some of the top work which can easily be repaired or replaced afterwards, because you will probably find that it has to be repaired pretty often. I have known more than one plant crippled from the start because sufficient margin had not been allowed for unforeseen foundation conditions.

Install a crusher that is well above its work under ordinary conditions, otherwise trouble will be experienced when working with very wet coal in the rains. In addition to the periodic stoppages of an elevator for oiling, cleaning, repairs, etc., the buckets have a habit of not filling up to full capacity, so that if you require to carbonize 300 tons of coal per day, the capacity of the elevator should be not less than 40 tons per hour.

Erect a concrete bunker of three days' capacity.

If you know that the coal you are going to carbonize is a good coking coal, do not install a compressor. Hand-charging at Giridih with coal containing the same percentage of moisture as for compressed charges gave 12 per cent less coke per oven, but the coking time was 13 per cent less, a slight gain in favor of hand charges. The point, however, is that when hand charging, the coal can be used dry, whereas it must contain about 11 per cent of water for compression, and we obtain a clear 10 per cent extra output by hand charging dry coal over our original method of compressing.

For charging the ovens, have an electrically driven charging car on the oven tops, and a mechanical leveller, but have the latter so designed that the oven is filled above the spring of the arch, as the ones usually supplied leave too much space between the top of the charge and the roof of the oven.

Have as many of the tar and liquor tanks as possible built of ferro-concrete, as the gases from the ammonia liquor soon begin to eat away wrought-iron sheets. If metal tanks have to be erected, the inside of the tops should be well painted, tarred and finally varnished.

It is not the custom in coke-oven practice to install spares in the pumping line, but where there are, say, three similar pumps doing different classes of work, a spare one should be insisted on.

I would say to the coke-oven manager, "Watch your suction." My experience has proved that this is of even more importance than the average coke-oven man considers.

Even anyone not particularly interested will easily understand that with such large coking chambers it is impossible to avoid occasional cracks and open joints, consequently given a pressure in the oven, the chimney is bound to draw oven gas into the heating flues. At the same time it is essential that air be not drawn into the oven from the flues. I am always hoping that someone will invent a reliable pressure governor to be fixed between the ovens and the exhauster.

Do everything possible to minimize the loss due to evaporation of ammonia from the liquor, between its production and its conversion into sulfate. Owing to the low vapor tension of ammonia, some loss cannot be avoided under any circumstances any more than water can be prevented from evaporating in hot dry weather, but the loss quickly increases with any rise in temperature or exposure of the liquor to the atmosphere. Keep all liquor seal pots and tanks well covered, and when pumping liquor see that the mouth of the delivery pipe is well below the usual level of the liquor in the tank, as the general method of pumping into the top of a tank and allowing the liquor to fall cascade fashion is a fruitful source of loss of ammonia. We have increased our production of ammonia quite appreciably by small alterations in this direction.

Have all your tar and liquor pipes properly trenched so that they can be inspected regularly. If it is absolutely necessary to bury any pipe, fill in with good clayey soil and not with cinders or ashes, as these quickly lead to corrosion of the pipe.

Owing to the now greatly increased cost of material, the preservation of the plant is of greater importance than ever. Tar is cheap. Use plenty. It is a most excellent preservative for both wood and iron. Always boil the tar before applying it, and it is preferable to add a very small quantity of lime when boiling.—Paper presented before the Mining and Geological Institute of India and reprinted by *The Science and Art of Mining*, Oct. 16, 1920.

RELATION OF AIR PRESSURE TO DRILLING SPEEDS OF HAMMER DRILLS

By H. W. SEAMON

THESE data were collected during a series of tests made at the property of the United Verde Copper Co. to determine the most economical air pressure for the operation of hammer drills under the varying conditions of use, and to investigate the variation in drilling speed at different air pressures. About 1,500 tests were made on twelve models of drills, at gage pressures ranging from 40 to 130 pounds. No effort was made to bring theory and practice into accord; but rather to formulate sundry empirical rules covering the average variation of the results obtained. However, these rules on the performance of hammer drills, based on the air pressures as the main variable are not necessarily of universal application; they apparently satisfy the results obtained in this particular series of tests.

The drilling conditions at this property vary widely. An average of twenty-one machine shifts to a 3-ft. round is necessary in some of the development work; while an advance of 56 ft. has been made in seven shifts in the "oxide" ground. This wide range of conditions precludes the adoption of one type of drill as a standard; consequently almost every kind of hammer drill sold in this country has been tested during the past few years. At the present time, sixteen different models of drills are in use, of which two types of the heavy (150 to 160 lb.) mounted drills, one of the light mounted drill, one stoper and two-hand plugging drills are considered as standard.

Inspection of the several tabulated results shows that:

1. There is little or no increase in mechanical efficiency of the drills above 90 lb. pressure.
2. The distance drilled per air indicated horse-power is a maximum for the jackhammer type at 90 lb. and increases at a slow rate for the other machines at the higher pressures.
3. The average thermal efficiency is a maximum at about 95 lb.
4. The factor of desirability, while increasing as the pressure, shows a comparatively slow rate of increase for pressures above 100 lb.
5. The average drill is made to be used at a pressure of 80 lb. or less, and the use of pressures much exceeding this would invalidate the present replacement agreements with the manufacturers, thereby increasing the upkeep cost.
6. The increased breakage at the higher pressures, with the consequent greater loss of time of the drill runner in changing or repairing the machine, would tend to reduce the factor of desirability.
7. The increased breakage of drill steel would tend to limit the pressure, although there are not sufficient data on this point to determine the maximum.

From the foregoing, it would seem that under the conditions obtaining at this property, about 95 lb. is the most economical gage pressure.—To be presented at New York Meeting, Feb. 14-17, 1921.

CALCULATION OF ORE TONNAGE AND GRADE FROM DRILL-HOLE SAMPLES

By JAMES E. HARDING

THE usual method of sampling mineral deposits is to drill holes and assay the sludge or core. Though the results thus obtained may not represent the true average value of the deposit; it is on these results that estimates of practically all large orebodies are made. In a large number of cases, the results of exploitation fall far short of the estimated value of the orebody.

The standard method of making these estimates is to find the cubic contents of triangular prisms, in the apices of which the drill holes are placed, by multiplying the surface area by the average depth of the ore in the three drill holes and then multiplying the cubic contents by the specific gravity of the ore or rock to find the tonnage. The assay value is found by dividing the sum of the products of the depth of ore in each hole and the corresponding assay value by the sum of the depths of the ore in the three holes. As the latter part of this method is subject to many mathematical errors, it should not be depended on. Some engineers, therefore, use a discount factor, but as this factor is either arbitrarily selected or is obtained by obscure methods, the results are no better than guesswork.

The standard method is correct when the drill holes are so laid out that the triangular prisms are equilateral in cross-section. But as ore deposits cannot always be drilled into at regular intervals, and because of the human factor, if many holes are drilled, triangular prisms of all degrees of angularity are produced. In such cases it is necessary to assume that the influence of the different holes is not the same in all directions, which assumption, of course, is absurd.

The area of the triangular prism is usually found by scaling; an orebody of sufficient size to justify churn drilling is too large to be handled conveniently on maps having a scale.—To be presented at New York Meeting, Feb. 14-17, 1921.

PLATINUM OCCURRENCES IN THE SOUTH AFRICAN UNION

FOR several hundreds of miles along the margin of the Bushveld granite area in the Transvaal, pseudostratified segregations of chromite associated with platinum have been noted. These are several feet in thickness, and of quite workable size and extent.

They have so far not been opened or exploited, but from time to time samples have been assayed. These usually contain from 35 per cent to 45 per cent chromic oxide. Samples from the north of the Lydenburg district, however, yield up

to 54 per cent. Unfortunately, this portion of the country lies over 50 miles from a railway and is inaccessible, but a reconnaissance has been made by the Railway Department, and in time the district will be opened and the deposits brought within reach of a market. So far only obvious outcrops have been tested, and obvious outcrops of all minerals tend to be the most siliceous, these resisting denudation, where the richer deposits weather away. The richer outcrops therefore become subsurface, and must be sought for by regular prospecting. These chrome ores are said by the Mines Department to contain an appreciable quantity of platinum, and certainly deserve attention.

The occurrence of platinum and the allied group of metals in the black sands derived from the conglomerates of the Klerksdorp area has been noted. The quantity appears to make the occurrence worthy of attention, but so far nothing has been done.—Discoveries noted in South African Mining and Engineering *Journal* of Sept. 18, 1920.

ELECTROLYTIC ZINC PLANT AT GREAT FALLS, MONT.

By FREDERICK LAIST, F. F. FRICK, J. O. ELTON, and R. B. CAPLES

ABOUT six years ago the Anaconda Copper Mining Co. decided to investigate the possibility of extracting zinc from the ores of certain mines in the Butte district. These ores are of a complex character and contain so much iron and lead that the concentrate contains only 33 to 35 per cent zinc.

Investigations showed that while a high-grade concentrate could not be obtained by ordinary methods, such as tabling and magnetic treatment, a fair grade could be made by the Horwood process. In this method, the concentrate resulting from the flotation of all of the sulfides is given a light roast and this calcine is subjected to flotation in the presence of a large amount of sulfuric acid; the resulting concentrate contains most of the zinc and a residue contains most of the iron. The fact that the lead, copper, and silver are divided approximately equally between the zinc concentrate and the iron residue and the large consumption of acid, which ranged from 50 to 100 pounds per ton of concentrates were serious objections to this plan. The zinc recovery, moreover, was low, as a considerable percentage invariably accompanied the iron. While a profit might be made on the ores by the use of this process, it was thought that other and more promising methods might be devised.

After carefully studying the field and doing some laboratory work on various processes that had been suggested, it was decided that the electrolysis of sulfate solutions was the most promising. The only way to obtain a good zinc deposit is to have the electrolyte free from all metals more electronegative than zinc, such as copper, cadmium, lead, arsenic, antimony, etc. Arsenic and antimony are particularly injurious, causing very poor current efficiency and small yield per horse-power when present in amounts so small as almost to defy detection—1 mg. or less per liter.

An aluminum plate made the most suitable cathode and a lead plate the most suitable anode. Some of the lead anodes have been used for three years and seem to be just as good as when put in.

On December 13, 1915, ground was broken at Great Falls for a plant that would be able to produce 100 tons of zinc per day, or 6,000,000 pounds per month.

In 1918 the plant was enlarged to make 150 tons per day, or 9,000,000 pounds per month. The plant is of permanent and up-to-date construction throughout; the buildings are brick and steel and all floors are concrete.

Much has been said about the difficulty of roasting zinc concentrates to render the zinc soluble in the presence of considerable iron. It is not difficult to make a calcine containing 82 per cent of its zinc in soluble form in 2 per cent H_2SO_4 from a concentrate that contains 33 per cent zinc to 20 per cent iron.

LEACHING DIVISION

The leaching is continuous and is carried out in two steps: (1) A neutral leach where all the calcine and approximately one-half of the total acid is added; (2) an acid leach where no calcine and the remainder of the acid is added.

The results of the acid leaching system are: (1) Solution of the remainder of the acid-soluble zinc and the copper; (2) final separation of the solids from the zinc and copper solutions; (3) roughing out of the copper and chlorine; (4) solution of sufficient iron to guarantee the removal of arsenic and antimony in the neutral leach step; (5) elimination of the arsenic and antimony which are only partly redissolved in dilute acid. A tank 12 feet in diameter by 12 feet deep was fitted with an air-lift agitator and used to dissolve the iron and scrap zinc for precipitating the copper. In this tank sufficient scrap iron and zinc were added to guarantee the desired result. The adoption of this scheme effected material saving of zinc dust in the purification plant.

The failure of the early experimenters to recognize the harmful effects of minute quantities of certain impurities is the principal reason for their disappointment.

ELECTROLYZING DIVISION

The tank house contains 864 cells divided into six electrical or solution units. The cells are 10 ft. 3 in. long, 2 ft. 10 in. wide, by 5 ft. deep. They are made of wood with a lead lining and are bolted together with heavy ¾-in. iron bolts at the end. Each cell contains 28 anodes and 27 cathodes. The cathodes are approximately 2 ft. by 3 ft. 6 in. by 3/16 in. thick and have a copper contact bar riveted on the top so that 3 ft. of the cathode is submerged; they are spaced 4 in. on centers at right angles to the solution flow.

DETERIORATION OF ALUMINUM CATHODES

When the gas leaves the surface of the cell, it atomizes a certain amount of the acid electrolyte, part of which comes in contact with the exposed surface of the aluminum plates. As these are relatively warm, the water evaporates, leaving a concentrated acid which causes a constant deterioration of that portion of the plate exposed above the solution level. When aluminum sells at 50 cents per pound, the aluminum cost approximates 75 cents per ton of zinc deposited. So far we have been unable to find a coating that will resist the acid for any length of time. Welding was suggested as a possibility, but it has been impossible to satisfactorily weld two pieces of plate aluminum.

ANODES

The lead anodes were made by casting the lead completely over ⅜ by 1¼ in. copper anode bar and cutting away the lead on one end so that the conductor bar made contact with the copper of the anode bar.

GLUE

Between 1 and 1½ oz. of glue per ton of metal produced, depending on the amount of impurities in the electrolyte has been added at 2-hr. intervals since the plant has been in operation. The judicious use of glue gives a dense deposit resulting in better melting recoveries of zinc.

MELTING DIVISION

The zinc-casting plant contains two coal-fired reverberatories with a capacity of from 100 to 125 tons per furnace and one electric furnace with a daily rated capacity of 200 tons. After a six-months' trial the use of the electric furnace was discontinued.

COAL-FIRED REVERBERATORIES

Zinc cathode sheets are apt to be porous to a certain extent and one side is covered with sprouts or raised spots. Even when melted in a covered crucible, from 4 to 5 per cent of dross is formed. The best recovery of the metal over a month's operation was 96½ per cent; 3½ per cent of the metal went

to form dross, which assayed 83½ per cent zinc, showing that approximately one-sixth of it was metallic.

The zinc-melting reverberatories are made of common brick below the metal line and of firebrick above. To avoid metal leakage the whole furnace is set in a sheet-metal pan, which is supported by I beams set on concrete piers. This construction permits air cooling of the bottom.

BAG HOUSE

The bag house originally contained eleven sections of 138 bags, each 18 in. by 30 ft.; it is so arranged that any section can be cut out for shaking or repairs. The building is of brick and steel with wooden sheeting and composition roofing. At first the gases, after being filtered through the bags, were allowed to diffuse into the air from louvers in the top of the bag house; the small amount of sulfur dioxide, 0.5 per cent by volume, however, made working conditions very disagreeable. The bag-house openings were therefore connected to the main flue system, which discharges all the smelter gases at an elevation of 500 ft. above the surrounding country. In 1918 six sections were added to provide additional capacity so that the matte could be converted at Great Falls.

RESIDUE SMELTING

The object of the residue treatment is to collect the maximum amount of copper, gold and silver in a leady matte with a minimum amount of zinc and to slag as much of the zinc as possible, while making a fume rich enough in lead to ship as a lead product. After several months of experimental work, the slag decided on as the most economical was 29 to 30 per cent FeO, 27 to 28 per cent silica, 16 to 17 per cent lime, and 10 to 11 per cent zinc. Over a period of six months when smelting a residue of the approximate analysis 15 per cent lead, 13 per cent zinc, 2 per cent copper, 23 oz. silver and 0.07 oz. of gold, 12 per cent silica, 29 per cent iron oxide, the recoveries were: Copper, 90.78 per cent; gold, 74.05 per cent; silver, 93.04 per cent; lead, 72.65 per cent.—Abstract of paper to be presented at the New York Meeting, Feb., 1921.

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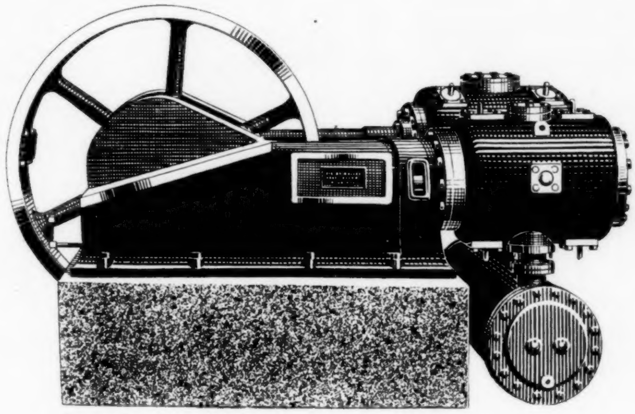

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